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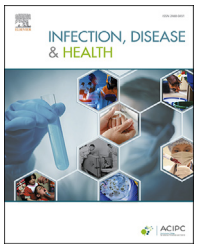

Research paper

Care bundle for the prevention of peripheral venous catheter blood stream infections at a secondary care university hospital: Implementation and results

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Peripheral venous Catheterization;
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Abstract *Background:* Venous catheterization for diagnostic and therapeutic purposes is part of routine hospital practice, as approximately 70% of hospitalized patients have a peripheral venous catheter (PVC). This practice, however, can lead to both local complications, (e.g., chemical, mechanical and infectious phlebitis) and systemic complications (e.g., PVC-related bloodstream infections [PVC-BSIs]). Surveillance data and activities are central to preventing nosocomial infections, phlebitis and improving patient care and safety.

The aim of this study was to evaluate the impact of a care bundle on reducing PVC-BSI rates and phlebitis at a secondary care hospital in Mallorca, Spain.

Methods: Three-phase intervention study targeting hospitalized patients with a PVC. The VINCat criteria were used to define PVC-BSIs and calculate incidence. In phase I (August

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—December 2015), we retrospectively analyzed baseline PVC-BSI rates at our hospital. In phase II (2016—2017), we conducted safety rounds and developed a care bundle with the goal of reducing PVC-BSI rates. In phase III (2018), we expanded the PVC-BSI bundle to prevent phlebitis and analyzed its impact.
Results: The incidence of PVC-BSIs decreased from 0.48 episodes per 1000 patient-days in 2015 to 0.17 episodes per 1000 patient-days in 2018. The 2017 safety rounds also detected a reduction in phlebitis (from 4.6% of 2.6%). Overall, 680 healthcare professionals were trained in catheter care and five safety rounds were conducted to assess bedside care.
Conclusion: Implementation of a care bundle significantly reduced PVC-BSI rates and phlebitis at our hospital. Continuous surveillance programs are needed to adapt measures to improve patient care and guarantee safety.

Highlights

- Implementation of care bundles reduced PVC-BSI rates.
- There are needed surveillance programmes to adapt measures for patient safety.
- Training in catheter care for healthcare professionals reduces infections.

Introduction

Venous catheterization for diagnostic and therapeutic purposes is part of routine hospital practice, as approximately 70% of hospitalized patients have a peripheral venous catheter (PVC) [1]. Venous catheterization, however, can lead to both local complications, such as chemical, mechanical, or infectious phlebitis, and systemic complications, such as PVC-related bloodstream infections (PVC-BSIs) [2]. A nationwide study of Spanish hospitals showed PVC to be one of the most frequent sources of nosocomial bacteremia. Moreover, phlebitis was clinically evident in 62.9% of episodes and proved to be an independent predictor in certain units [3]. These infections compromise patient safety, causing delayed healing, complications, longer hospital stays, considerable increases in resource consumption, and higher mortality. In the above study, PVC-BSIs were associated with a mortality rate of 5.7%. In another study, they have been linked to a mean estimated cost increase of €15,151 [4]. Incremental costs associated with catheter-related BSIs (CRBSIs) can vary anywhere between €27,232 and €68,983; the resulting costs for national healthcare systems can be as high as €54 million to €130 million a year depending on the country [5].

It is estimated that 65—70% of PVC-BSIs are preventable [6], with evidence showing that these infections can be minimized through safe and appropriate care [7,8]. Phlebitis is the most common complication, estimated to account for 3—12% of all PVCs [9]. Improvements in care practice are needed and require a new approach to PVC management based on proactive patient assessment and improved procedures for catheter insertion and maintenance and vein preservation. Reducing PVC-BSIs and ensuring patient safety should be a fundamental goal of all hospitals. In a prospective cohort study published in 2010, CRBSIs were the main complications reported by 15 Spanish hospitals, with 821 episodes (almost 25% of all nosocomial BSIs) [10].

Spain does not have a national healthcare-association infection surveillance program, but it does have regional programs that compile data from a significant number of centers. Data from the Catalan surveillance program (VINCat) serve as a benchmark for our hospital due to the similarities of the healthcare systems. VINCat is run by the Catalan Health Service and represents a unified surveillance system for nosocomial infections in hospitals across Catalonia [11]. Its mission is to contribute to reducing infection rates through active and ongoing epidemiological surveillance. The overall program is based on the work carried out by multidisciplinary infection control teams at Catalan hospitals. The VINCat publishes annual incidence rates for PVC-BSIs reported by member institutions. Rates at secondary care hospitals for the period 2015—2018 were within the range of 0.05—0.06 episodes per 1000 patient-days [12]. Monitoring of PVC-BSI rates should be compulsory, as it allows comparison of infection rates between hospitals and even hospital departments, and also guides the implementation of control measures.

Interventions aimed at reducing CRBSIs in intensive care units (ICUs) have shown that the application of bundles of measures can significantly reduce CRBSI incidence [13,14]. Bundles are defined by the Institute for Healthcare Improvement as "a group of interventions related to a disease process that, when executed together, result in better outcomes than when implemented individually" [15]. The CRBSI prevention bundle includes evidence-based measures such as hand hygiene promotion, use of chlorhexidine alcohol solution for skin antisepsis, full barrier precautions, daily review of the need for catheterization, and femoral site avoidance [16]. In 2009, hospitals participating in the VINCat program launched an ICU "Bacteremia Zero Program" [17]. A similar intervention targeting catheterization on all conventional wards was implemented in 11 hospitals involved in the program in the same year [13]. This multimodal intervention significantly reduced the overall rate of CRBSIs outside the ICU as well as CRBSIs originating in central venous catheters. It did not succeed, however, in decreasing the rate of PVC-BSIs [13].

The aim of this study was to determine the effectiveness of a care bundle designed to reduce PVC-BSIs and phlebitis.

Methods

Son Llàtzer University Hospital is a secondary care hospital located on the island of Mallorca in Spain. It serves a population of 264,972 inhabitants and has 417 beds, 13 operating rooms, and 16 ICU beds. The average occupancy rate is about 78.4%. There are 17,545 hospital discharges a year and 13,712 surgical interventions [18].

This study was conducted in three phases. In phase I, we performed a retrospective analysis of PVC-BSI rates between August and December 2015 to ascertain the baseline (pre-intervention) situation. In phase II (2016–2017), we developed and implemented a care bundle including hand hygiene monitoring, skin antisepsis, connector disinfection, dressing maintenance, daily review of the need for catheterization, and timely removal of unnecessary PVCs to prevent and reduce the incidence of PVC-BSIs. In phase III (2018), we evaluated the impact of the care bundle and implemented appropriate improvements. General and department-specific PVC-BSI rates continued to be monitored throughout the two intervention phases, and in all cases, the causative microorganisms were investigated.

All patients aged ≥18 years with a PVC on inpatient wards at Son Llàtzer University Hospital were included. Intensive care, psychiatric, and pediatric patients were excluded.

Intervention phases

Phase I: Retrospective observational analysis to determine baseline situation (August–December 2015).

In collaboration with the microbiology department, we collected data from the medical records of hospitalized patients aged ≥18 years with positive blood culture results. Information on patient-days was obtained from the hospital administration system to calculate PVC-BSI incidence. Calculation of PVC-BSI rates was completed in August, as the significant rates detected warranted the implementation of immediate measures to prioritize patient safety. During this period, a multidisciplinary catheter infection team (MCIT) comprising sepsis, microbiology, internal medicine, and research units was set up.

Phase II: Intervention phase to implement improvement strategies (January 2016–December 2017). In this second phase, we continued to monitor PVC-BSI rates and implemented a number of measures aimed at their reduction. We have divided phase II into two periods (IIA and IIB) to facilitate the description of the interventions implemented. The specific measures included in phases II and III are summarized in Table 1.

Phase IIA. 2016

a. Evidence-based update of PVC insertion and maintenance procedures following a review of clinical practice guidelines [19].
b. In-person training of doctors, nurses, radiology specialists, orderlies, and nursing assistants focused on the application of evidence-based practices related to PVC insertion and

Table 1 Components of PVC-BSI prevention bundle.

PHASE	BUNDLE COMPONENTS	LEVEL OF EVIDENCE ([a])
IIA	Face-to-face training on evidence-based best practices in catheter care	IA
	Evidence-based update of PVC insertion and maintenance procedures following a review of clinical practice guidelines	IA
	Implementation of safety rounds	IB
IIB	Incorporation of pharmacy department into multidisciplinary catheter infection team	IB
	Incorporation of midline catheters	IB
	Testing of new material resources: bioconnectors and isopropyl alcohol disinfection caps for MLCs	IA-II
	Substitution of 0.5% alcoholic chlorhexidine for 2% alcoholic chlorhexidine	IA
	Active engagement of patients in catheter care	IB
	Incorporation of computer reminders about proper access and catheter maintenance	IB
	Involvement of hospital's nursing care, safety, and infectious diseases committees	IB
	Creation of vascular access subcommittee within infectious diseases committee	IB
III	Activation of new computerized registry in nursing management system	IA
	Incorporation of hospital into Phlebitis Zero Project	IA-IB
	Placement of hydroalcoholic solution dispensers in all hospital rooms and wards	IB
	Creation of hotline staffed by personnel trained in vascular access, infection prevention, and patient safety	IA

MLCs = midline catheters; **PVC** = peripheral venous catheter; **PVC-BSI** = peripheral venous catheter–related blood stream infection.
[a] According to 2011 Centers for Disease Control and Prevention guidelines [16]: IA. Strongly recommended for implementation and strongly supported by well-designed experimental, clinical, or epidemiologic studies. IB. Strongly recommended for implementation and supported by some experimental, clinical, or epidemiologic studies and a strong theoretical rationale; or an accepted practice (e.g., aseptic technique) supported by limited evidence. II. Suggested for implementation and supported by suggestive clinical or epidemiologic studies or a theoretical rationale.

maintenance and awareness-raising on the importance of timely removal of unnecessary lines and proper hand hygiene. The training sessions were adapted as necessary to the different groups of healthcare personnel. The sessions comprised a standard presentation highlighting the risks associated with CRBSIs, surveillance rates at the hospital, the pathogenesis of infections, and recommendations for prevention.

Phase IIB. 2017

a. Implementation of safety rounds on all hospital wards and evaluation of the impact of the care bundle on PVC-BSI prevention. Similar rounds have been conducted at other hospitals as part of a multimodal strategy for PVC-BSI prevention [20]. The rounds had an educational purpose and were carried out twice a month, with analysis of the following variables: documenting of catheter device and dressing changes, number and type of PVCs inserted, condition and adequacy of dressing, presence of phlebitis, use of three-step stopcocks with caps, traces of blood in the system, and presence of disconnected devices, pre-filled syringes, and unnecessary lines (according to prescribed drug treatment). This checklist, implemented in 2017 only, enabled detection of specific problems to guide the implementation of new actions in later phases.
b. Incorporation of the pharmacy department into the MCIT to detect inappropriate PVC use for certain drugs according to pH, osmolarity, and treatment duration [21,22].
c. Incorporation of new vascular access catheters for intravenous therapies following clinical guideline recommendations on suitability according to pH, osmolarity, and treatment duration [23]. In brief, third-generation polyurethane midline catheters (MLCs) were added for patients who needed prolonged vascular access and complied with the established recommendations.
d. Testing of new material resources: bioconnectors and caps for MLCs in pilot units (these have been found to reduce PVC-BSIs [24]), monitoring of proper use, and administration of a questionnaire at the end of the pilot phase to assess the nurses' experiences.
e. Substitution of 0.5% alcoholic chlorhexidine for 2% alcoholic chlorhexidine, as recommended by clinical guidelines [19].
f. Active engagement of patients in their own catheter care by showing them a video with four images linked by music briefly illustrating how they could help care for their catheter, when to notify a nurse, and what warning signs and symptoms to look out for [22].
g. Incorporation of computer reminders about proper access and catheter maintenance shown to all professionals when they logged in on certain days of the week [23].
h. Involvement of the hospital's nursing care, safety, and infectious diseases committees to garner their support for the improvement strategies, considered essential for progress and a shared multidisciplinary vision [2].

Phase III: Implementation of new measures based on findings from 2017 and evaluation of their impact on PVC-BSI prevention (2018).

Analysis of PVC-BSI rates continued in phase III to assess the outcomes of the measures adopted. We also implemented new improvement measures derived from the multidisciplinary work and results of the 2017 safety rounds.

a. Creation of a vascular access subcommittee within the infectious diseases committee.
b. Activation of a new computerized registry in the nursing management system with access to relevant training for all nursing staff on the wards analyzed: internal medicine, digestive, cardiology, hematology, oncology, neurology, pneumology, and general surgery. The registry contains the following items: ward; catheter insertion date and time; catheter type and caliber; insertion site; purpose; date, time, and reason for removal; phlebitis grade according to the Maddox visual assessment scale included in the Phlebitis Zero Project [25]. This registry information was considered important for determining the main causes of PVC-BSIs. In addition, it provides more indicators of the quality of nursing care that could be used as benchmarks.
c. Incorporation of the hospital into the Phlebitis Zero Project, a nationwide program designed to determine and analyze the incidence of PVC-related phlebitis. Its goal is to reduce the incidence of both phlebitis and PVC-BSIs by enabling prompt action (before the onset of bacteremia). Being part of this project gave the hospital's medical and nursing staff permanent access to its accredited online training platform.
d. Placement of hydroalcoholic solution dispensers in all hospital rooms and wards to improve hand hygiene awareness and behaviors among all healthcare personnel.
e. Creation of a hotline staffed by personnel trained in vascular access, infection prevention, and patient safety to advise nurses on the most appropriate PVCs according to patient characteristics and preferences and type and duration of endovenous treatment.

Definitions and identification of microorganisms

A catheter tip culture was considered, but not required, to confirm PVC-BSIs. Presence of phlebitis was defined as a PVC-related inflammation of the vein wall with associated symptoms such as pain, erythema, swelling, induration, palpable venous cord, or purulent discharge at the insertion site [2]. Microorganisms were recovered from the blood using the automated Bactec FX system (Becton Dickinson) and identified through matrix-assisted laser desorption ionization and time-of-flight mass spectrometry (MALDI-TOF and VITEK MS).

Analysis

The following formula was used to calculate annual PVC-BSI incidence: total number of PVC-BSI episodes a year per 1000 patient-days based on VINCat criteria [13]. Patient-days were obtained from administrative data. To assess the impact of the intervention, we compared the incidence density of CRBSIs for 2015 with that of 2018 using the Z-test statistic for independent rates. To assess the impact of the intervention on the implementation of preventive measures, we compared adherence rates observed in the baseline point-prevalence study (phase I) with those observed at the two subsequent pooled time points (phase II and III) using the Z-test for independent proportions. The two-sample Z-test was used to analyze annual differences, while the Cochran-Armitage trend test was used to assess the significance of annual trends. All statistical analyses were performed using the IBM SPSS statistics software v23.0 (SPSS Inc., Chicago, IL, USA).

Results

In the first period (second half of 2016), 680 healthcare professionals from different areas of the hospital participated in face-to-face training on evidence-based best practices in catheter care. In the bundle implementation period, we studied 101 patients (65.7% male) with a mean age of 70 years (range, 16—99 years). The overall PVC-BSI rate fell from 0.48 episodes per 1000 patient-days (absolute value, 19 episodes) between August and December 2015 to 0.34 episodes per 1000 patient-days (36 episodes) in 2016, 0.29 episodes per 1000 patient-days (28 episodes) in 2017, and 0.17 episodes per 1000 patient-days (18 episodes) in 2018 (Fig. 1).

The cardiology, digestive medicine, and internal medicine departments had the highest infection rates at all time points (Fig. 2). Internal medicine patients were the oldest, with a mean age of 77 years. The mean age of digestive and cardiology patients was similar, at 64 and 63 years, respectively.

In 2017, five twice-monthly safety rounds were conducted on all wards targeted by the intervention. These rounds continued to be conducted periodically throughout the study period. Several notable findings were observed on comparing the results of the safety rounds conducted in the first quarter of 2017 and the first quarter of 2018. The most notable was an almost two-fold reduction in phlebitis (from 4.60% to 2.60%). The rounds also led to the detection of numerous problems not recorded in the patients' clinical histories. Activation of the new computerized registry in the nursing management system led to an increased detection of dressings considered to be in poor condition (evident traces of organic matter, moist, poor occlusion) or inadequate (from 11.20% to 15.90%). Monitoring of the registry and improved knowledge acquired through training made it possible to evaluate the usefulness of inserted catheters. The proportion of unnecessary PVCs detected also increased (from 21% to 26%). Most of these were in the cardiology department and were probably "just-in-case" catheters, that is catheters left in place should they be needed for an emergency situation. As of December 31, 2018, 234 healthcare professionals had completed the Phlebitis Zero Project training program.

Also in 2017, three nurses were trained in ultrasound-guided MLC placement, a measure that led to improved placement of 72 MLCs inserted between April 2017 and December 2018. The pharmacy department guided these nurses on choice of venous catheter according to pH and osmolarity. The switch from 0.5% chlorhexidine to 2% chlorhexidine was made across the hospital, affecting all clinical units equally.

Gram-negative bacteria were the main causes of PVC-BSIs in 2015, 2016, and 2017. In 2018, however, gram-positive bacteria were responsible for 64.7% of all episodes (Table 2).

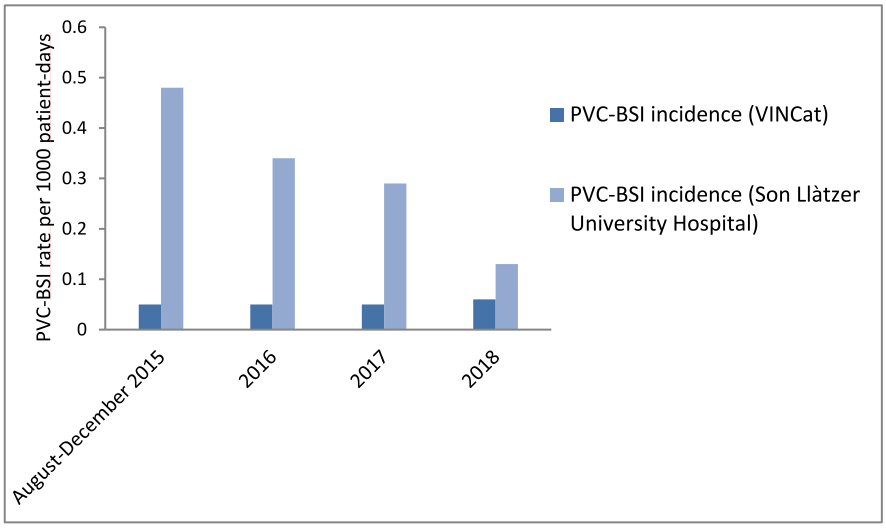

Fig. 1 Changes in the incidence of peripheral venous catheter—related bloodstream infections (PVC-BSIs) at Son Llàtzer University Hospital in Mallorca compared with data from the VINCat surveillance program from 2015 to 2018.

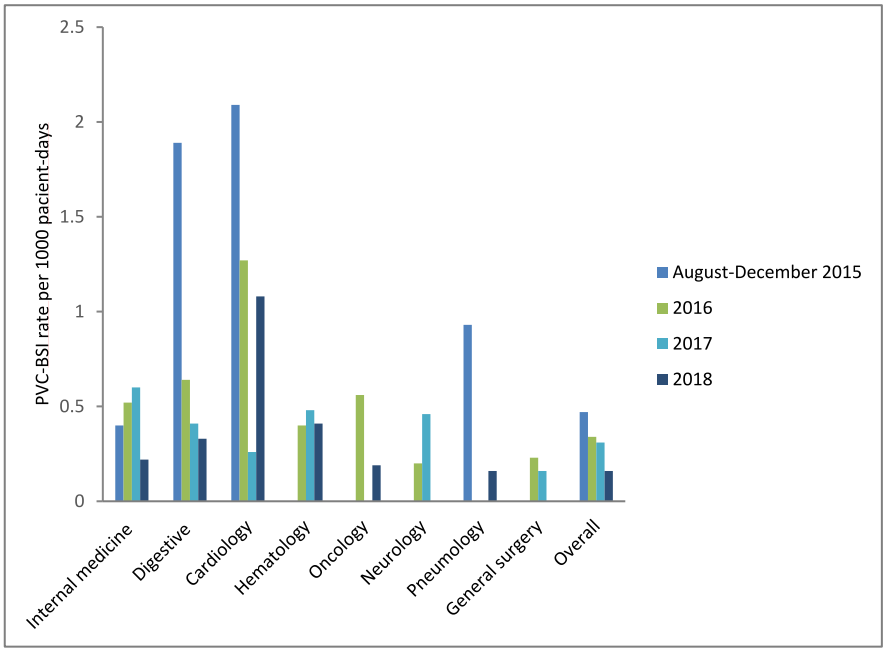

Fig. 2 Changes in the incidence of peripheral venous catheter—related bloodstream infections (PVC-BSIs) by department. Departments with no results shown for a given year had no PVC-BSIs in that year.

Table 2 Microorganisms isolated between August 2015 and December 2018.

	Gram-positive bacteria (*Staphylococcus aureus, MRSA, MSSA; Staphylococcus epidermidis, Coagulase-negative Staphylococcus, Enterococcus* spp, *Streptococcus mitis*)	**Gram-negative bacteria** (*ESBL Escherichia coli, ESBL Klebsiella* spp., *Pseudomonas* spp, *Enterobacter cloacae, Proteus* spp., others)
August to December 2015, n (%)	8 (33.3)	14 (67.6)
2016, n (%)	15 (41.6)	21 (58.3)
2017, n (%)	12 (37.5)	20 (62.5)
2018, n (%)	11 (64.7)	6 (35.3)
Total study period, n (%)	**46 (42.6)**	**62 (57.4)**

ESBL = extended-spectrum beta-lactamase-producing bacteria; MRSA = methicillin-resistant *Staphylococcus aureus*; MSSA = methicillin-sensitive *Staphylococcus aureus*; spp = species.

Discussion

Implementation of the PVC-BSI care bundle at our hospital led to notable improvements in patient safety, supporting previous findings from a similar intervention implemented over a longer period at another Spanish hospital [7].

Few hospitals have ongoing, prospective surveillance program for PVC-BSIs, or clear actions to reduce infection rates to levels considered acceptable for hospitals providing a similar level of care. In our study we detected a possible association between PVC-BSIs and type of ward and unnecessary PVCs (delayed removal). This observation is consistent with reports by Sato et al. [26], who also found that the number of days between antibiotic initiation and the last positive blood culture is frequently higher in patients with delayed versus timely PVC removal. Careful insertion site examination can also contribute to a reduction in PVC-BSIs [25].

Recent studies on PVC-BSIs have found evidence of gram-positive infections [7]. In our study, most PVC-BSIs detected between 2015 and 2017 were caused by gram-negative microorganisms, possibly due to inadequate hand hygiene [2]. To address this, hydroalcoholic solution dispensers were placed in all hospital rooms and wards in 2018.

Berger et al. [27] found an association between delayed PVC removal and gram-negative infections and changes in skin microbiota in patients with prolonged hospitalization. Ripa et al. [28], in turn, reported an increase in gram-negative PVC-BSIs between 1996 and 2016 associated with hospital stays longer than 7 days with a catheter *in situ* for more than 3 days, beta-lactam treatment, and having undergone surgery. We did not evaluate these factors in our study, but will do so in future studies.

The safety round checklist items were chosen based on findings from previous phases of the study and shortcomings observed during the implementation of evidence-based

best practices. As noted by other authors [29], little has been published on which items could or should be monitored on nosocomial infection control rounds, or on whether these should be based on a prior assessment. The optimal frequency of these rounds also remains to be determined, as does the number of components a bundle should contain to prevent or significantly reduce PVC-BSIs. An additional consideration is that it is difficult to evaluate the impact of individual components within care bundles. Despite these challenges, PVC-BSI prevention bundles, apart from reducing the risk of mortality and morbidity, can result in significant healthcare cost savings.

Limitations

Our study has some limitations. It is a single-center study, and several factors that could be relevant for predicting PVC-BSI risk were not analyzed, including number of catheter days and type of intravenous treatment. Furthermore, the purpose-designed safety rounds to detect shortcomings in vascular access care were only conducted in 2017 because of limited resources and funding (the project was led by the nursing department). In the final phase of the intervention, however, these initial safety rounds were replaced by safety rounds within the Phlebitis Zero Project, which are conducted annually over a period of 15 days. Nevertheless, we are confident that the data analyzed are consistent, precise, and reliable considering the high number of BSIs evaluated within the framework of a well-consolidated infection surveillance program. Our findings may also have been influenced by confounders that we did not consider during data collection, such as fluctuations in patient acuity. The small sample size also meant that we had insufficient data to perform regression analysis to adjust for potential confounders. We are also missing data on degree of compliance with certain components of the bundle related to the use of material resources, such as hand hygiene practices. The impact of the switch to 2% alcoholic chlorhexidine is also unknown. Finally, because PVC-BSI bundles are multicomponent interventions, it is difficult to determine the usefulness of individual components.

Conclusions

Continuous monitoring and evaluation of PVC-associated complications, together with ongoing training, regular revision of care bundle, and application of best practices for patient safety, are crucial for excellence in clinical care. Multicenter studies are needed to accurately identify risk factors for PVC-BSIs and items to include in safety round checklists. Computerized systems could also further the implementation of effective tools to predict and prevent nosocomial infections.

The intervention described in this study can be adapted to the needs of other hospitals. Interventions of this nature require skilled management of resources to ensure the sustainability of a constantly evolving public healthcare system responsible for controlling nosocomial infections and guaranteeing safe vascular access in an ageing population with rising rates of chronic disease. Multidisciplinary approaches to vascular access are essential to patient safety and to achieving a shared, holistic vision. Appropriately trained nurses could play a key mediatory role within multidisciplinary teams committed to excellence and integrity in clinical care.

Authorship statement

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Provenance and peer review

Not commissioned; externally peer reviewed.

Ethics

This study was conducted in accordance with national ethical standards and the principles of the Declaration of Helsinki. Ethical approval was obtained from the Clinical Research Ethics Committee of the Balearic Islands in 2022

(ref: IB4907/22.) No diagnostic tests other than those required by routine care were performed; the same applies to sample collection. All data were treated as confidential, and records were accessed anonymously.

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