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# Central Venous Access Device Complications in Patients Receiving Parenteral Nutrition in General Ward Settings: A Retrospective Analysis

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**Abstract**

*Background:* Central venous access devices (CVADs) are used widely in acute clinical settings for the infusion of parenteral nutrition (PN) in patients who are unable to meet their nutrition requirements via the oral or enteral routes. The aim of this study was to characterize the frequency and nature of CVAD complications in patients receiving PN in general ward settings. *Methods:* A retrospective analysis of CVAD-related outcomes for adult patients who received PN from January 2014 to December 2016 was conducted. *Results:* A total of 629 CVADs were placed in 475 patients for parenteral administration in general ward settings during the 3-year study period. A total 104 (16.53%) episodes of CVAD-associated complications were reported during this period, including suspected line infection, leak at site, catheter blockage, and generalized patient sepsis. Overall, 13 CVAD catheter-related bloodstream infections (CRBSIs) were diagnosed in the patient cohort over 8695 PN feeding days, giving an incidence of 1.49 CVAD infections per 1000 PN feeding days. *Conclusion:* The results showed that patients receiving PN through CVADs within general ward settings experience CRBSI at rates no different from those reported within critical care settings. These findings demonstrate that with appropriate nursing care, CVADs appear safe when used for the administration of PN in general ward settings. (*JPEN J Parenter Enteral Nutr.* 2019;0:1–8)

**Keywords**

bloodstream infection; catheter complications; central venous access devices; total parenteral nutrition

## Clinical Relevancy Statement

Parenteral nutrition (PN) is now widely used in acute hospital general ward settings and is no longer limited to critical care areas. It is important to understand the complications associated with the central venous access devices (CVADs) used for the delivery of PN outside of the critical care environment. The results of this study, which characterized the frequency and nature of CVAD complications in ward-based patients, provides clinically relevant information for clinicians responsible for managing safe and effective general ward administration of PN.

## Introduction

Nutrition support is an essential part of disease management and has been used widely since the late 1960s.[1] The evidence indicates that between 20% and 50% of patients in hospitals experience some degree of protein energy starvation.[2] This result is not surprising considering that most investigations and surgical procedures require patients to receive nothing by mouth and that appropriate parenteral nutrition (PN) support is required to facilitate recovery.

PN involves the intravenous administration of energy, amino acids, electrolytes, vitamins, minerals, trace elements, and fluids to meet patients' metabolic needs.[3] PN can be used in both the short term and long term, when there is reversible or irreversible loss of gastrointestinal function and adequate nutrition cannot be met via the oral or enteral routes. The most common indications for short-term PN

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administration identified within the literature include patients with intestinal obstruction, prolonged ileus, malabsorption secondary to ulcerative colitis, major abdominal surgeries, or malignancies.[4,5] In addition, PN has also been identified as a potential venous irritant. Given its pH and high osmolality, PN is predominately administered using central venous access devices (CVADs).[6] As with other invasive devices, the use of CVADs for the administration of PN carries a significant risk of device-associated complications, including catheter-related bloodstream infection (CRBSI), site infection, catheter dislodgement, catheter occlusion, venous thrombosis, and device breakage/failure.[7,8] In addition, patients receiving PN via CVADs are at an increased risk of complications, compared with those with CVADs for other purposes, because the PN solution creates a high-risk medium for microbial growth. The high concentrations of glucose, amino acids, and intralipids promote both bacterial and fungal production growth, primarily staphylococci, enterococci, and *Candida* species.[6,9] PN has been identified as an independent risk factor for CRBSI because of the solution making a potential culture medium.[6] The incidence of CRBSI in patients administered PN is varied, with evidence indicating incidence rates ranging from 36.5 to 3.6 per 1000 catheter days.[10,11] If not addressed in a timely period, these complications can result in adverse patient outcomes, increased morbidity, mortality, length of hospital stay, and healthcare costs.[11,12]

Insertion of CVADs for patients receiving PN has traditionally been undertaken by medical practitioners, and these patients were managed in a critical care environment such as the intensive care unit (ICU).[13,14] However, advances in nutrition therapeutics and the evolution of nursing-led CVAD teams have led to an exponential increase in the proportion of CVADs that are inserted and maintained within general ward areas.[15] Despite these significant changes, evidence in relation to complications of CVADs associated with the administration of PN is based on studies conducted within critical care environments. There is little reliable evidence on CVAD complications specifically related to the administration of PN in general wards. Therefore, the aim of this study was to characterize the frequency and nature of CVAD complications in patients receiving PN in general ward settings by undertaking a retrospective analysis of data collected at a large principal referral and teaching hospital between January 2014 and December 2016.

## Methods

### *Study Design and Setting*

This study incorporated a retrospective, observational study design to investigate CVAD complications for all patients receiving PN at a 627-bed principal referral and teaching hospital in Sydney, Australia.

### *Patients*

Inclusion criteria were patients aged ≥18 years who were admitted to a general ward within the hospital between January 1, 2014, and December 31, 2016, and who received PN via any type of CVAD. Patients who received PN only in critical care environments were excluded from this study. Preexisting home parenteral nutrition (HPN) patients who were hospitalized during the study period were also excluded because management of CRBSIs in existing HPN patients differs from that in acute care patients.

### *Catheter Care*

The catheter care at the study hospital is centered on evidence-based practice and follows the local policy guidelines as well as the NSW Agency for Clinical Innovation guidelines "Central Venous Access Device Post Insertion Management." Catheter care includes CVAD dressing changes routinely every 7 days or if clinically indicated (wet or soiled) while maintaining asepsis; needleless injecting ports and CVAD sites are cleaned with antiseptic solution of 70% alcohol 2% chlorhexidine; the CVAD site is assessed at least once per shift and at more frequent periods if required; and a sterile, transparent, semipermeable adhesive dressing is used to cover the CVAD site.

### *Data Collection*

Patients' details were identified from the hospital's PN database, which was established in 2009 by the nutrition-support clinical nurse consultants (CNCs). All data in the PN database are entered prospectively by the CNCs until the PN is discontinued. Information captured in this database included demographics such as patient age, gender, diagnosis, and indications for PN. Additional CVAD information included device type, insertion site, CVAD dwell time, and the total number of parenteral feeding days. Data were also maintained on CVAD complications, including septic complications.

### *Outcomes*

The outcome of interest were the number of CVADs that were removed for CRBSI. CRBSI is the presence of bacteremia deriving from the CVAD and is often referred to as catheter-related or suspected sepsis, defined clinically as a fever (sudden and high temperatures of 38°C or greater) with associated rigors.[16] In this study, we also refer to non–catheter-related fever, in which the CVAD is not clearly indicated as the cause of the fever. CRBSI was defined as a positive CVAD lumen quantitative isolator culture with a positive peripheral-blood isolator culture caused by the same microorganism, with a 4–5 times greater growth from the catheter sample.[17] Catheter-tip–culture positivity was

defined as catheter-tip culture with a growth of >15 colony-forming units/mL from the inside of a distal catheter segment using semiquantitative microbiological techniques.[18]

### *Ethical Considerations*

Ethical approval was obtained from the hospital's Human Research Ethics Committee for this study as a quality-improvement project.

### *Statistical Analysis*

Data were obtained from the PN database and analyzed using Microsoft Excel. All analyses were performed based on the number of CVADs rather than the number of patients, meaning a single patient could have multiple CVADs. Categorical data were summarized using percentages and means, and standard deviation was calculated for continuous data. Incidence rates for culture positivity and the CRBSI rate per 1000 PN feeding days were calculated.

## Results

From January 2014 to December 2016, a total of 475 patients (235 females, 49.5%; 240 males, 50.5%) received PN in the general ward settings. The mean age of the patients was 60.02 ± 15.50 years (range 15–95). Participant demographics are described in Table 1, and participant CVAD details are summarized in Table 2.

**Table 1.** Demographics (N = 475).

| Demographic Categories | Frequency | Percentage, % |
|---|---|---|
| Gender | | |
| Male | 240 | 50.5 |
| Female | 235 | 49.5 |
| Age, y | | |
| 18–30 | 19 | 4.0 |
| 31–45 | 68 | 14.3 |
| 46–65 | 182 | 38.3 |
| 65+ | 206 | 43.4 |
| Indication for PN | | |
| Anticipated prolonged period of receiving nothing by mouth | 221 | 46.5 |
| Ileus | 54 | 11.4 |
| EPIC | 48 | 10.1 |
| Fistula | 34 | 7.1 |
| Bowel obstruction | 26 | 5.4 |
| Preoperatively | 13 | 3.0 |
| Anastomotic leak | 11 | 2.2 |
| Short gut | 8 | 1.7 |
| Pancreatic leak | 7 | 1.5 |
| Pancreatitis | 7 | 1.5 |
| Malnutrition | 6 | 1.3 |
| Other | 40 | 8.4 |
| Patients by specialty | | |
| Liver/peritonectomy unit | 328 | 69 |
| Colorectal | 65 | 13.7 |
| Upper gastrointestinal | 42 | 8.9 |
| Cancer services | 7 | 1.5 |
| Gastroenterology | 7 | 1.5 |
| Breast/Endo | 6 | 1.3 |
| Cardiothoracic | 6 | 1.3 |
| Urology | 5 | 1.0 |
| Other | 9 | 1.9 |

EPIC, early postoperative intraperitoneal chemotherapy; PN, parenteral nutrition.

### *Indication for PN*

The most common indication for PN was anticipated prolonged period of receiving nothing by mouth, predominantly due to gut rest after extensive gastrointestinal surgical intervention (n = 221, 46.5%), followed by postoperative paralytic ileus (n = 54, 11.4%) and early postoperative intraperitoneal chemotherapy (n = 48, 10.1%). Other indications for PN administration were patients with compromised intestinal integrity such as enterocutaneous fistulae, bowel obstruction, and gastrointestinal-tract injury such as perforations, anastomotic breakdowns, or spontaneous leaks. Overall, the length of time receiving PN ranged from 2 to 168 days with a median of 14 days. The 475 patients encompassed a total of 8695 parenteral feeding days (23.82 years).

### *Types of CVADs*

A total of 629 CVADs were placed in 475 patients during the 3-year study period. Almost half of the patients had a quadruple-lumen central venous catheter (n = 312, 49.60%), 34.66% (n = 218) had a double-lumen peripherally inserted central catheter (PICC), and 4.7% (n = 29) had implanted venous ports. Fifty-six percent of the patients (n = 350) had only 1 CVAD during the PN administration period. A total of 108 patients had multiple catheters inserted during the period of data collection, ranging from 2 (75 patients) to 9 (1 patient), with a mode of 2 catheters. A total of 202 (32.11%) antimicrobial (chlorhexidine) impregnated CVADs were used for PN administration. In September 2015, a change in practice of product selection of CVADs was decided upon. Historically, a chlorhexidine-impregnated CVAD had been inserted in the perioperative and ICU settings.

### *Reasons for Removal of CVADs*

A total of 16.53% (n = 104) of CVADs required removal for a number of CVAD-associated complications during the study period. The reasons for removal included catheter-related or suspected sepsis (53.52%, n = 38), non–catheter-related fever (42.25%, n = 30), generalized patient sepsis

**Table 2.** Types of CVADs.

| Types of CVADs | Frequency (%) |
|---|---|
| Quad-lumen Arrowgard (chlorhexidine-impregnated catheter) | 167 (26.5%) |
| Double-lumen power peripherally inserted central catheter | 162 (25.8%) |
| Quad-lumen standard central venous catheter | 136 (21.6%) |
| Double-lumen peripherally inserted central catheter | 46 (7.3%) |
| Implanted venous port | 29 (4.6%) |
| Triple-lumen Arrowgard (chlorhexidine-impregnated catheter) | 17 (2.7%) |
| Single-lumen peripherally inserted central catheter | 11(1.7%) |
| Double-lumen pressure-injectable peripherally inserted central catheter | 10 (1.6%) |
| Single-lumen Power peripherally inserted central catheter | 9 (1.4%) |
| Quad-lumen ABG+ central venous catheter (chlorhexidine impregnated) | 9 (1.4%) |
| Triple-lumen ABG+ central venous catheter (chlorhexidine impregnated) | 9 (1.4%) |
| Triple-lumen standard central venous catheter | 7 (1.1%) |
| Peripherally inserted central catheter, undefined | 7 (1.1%) |
| Single-lumen Hickman catheter | 7 (1.1%) |
| Double-lumen Hickman catheter | 2 |
| Single-lumen pressure Arrow peripherally inserted central catheter | 1 |

ABG+, Arrowg+ard Blue Plus; CVAD, central venous access device; Quad, quadruple.

(2.82%, n = 2), and redness at the CVAD insertion site (1.41%, n = 1). A detailed summary of the reasons for catheter removal is presented in Table 3.

### *Bacterial Spectrum of CTC+ and CRBSI+ CVADs*

Eighteen CVADs had a total of 20 culture-positive infections, with 10 separate microorganisms isolated. Of these, 13 were responsible for development of CRBSI. Overall, the most common microorganisms were *Staphylococcus epidermidis* (n = 5), *Klebsiella pneumoniae* (n = 3), and *Candida* (n = 3), accounting for a total of 55% of the isolates over the study period. Table 4 lists the microorganisms isolated in culture-positive and CRBSI CVADs.

### *Catheter-Related Bloodstream Infections*

CRBSIs occurred in 18 (25.35%) of the 71 CVADs that were removed for infective complications. This equated to 2.07 CVAD infections per 1000 PN feeding days (18 CVAD infections over 8695 PN feeding days). Further analysis of the 71 CVADs that were removed for suspected infection based on clinical judgment indicated that only 13 (18.31%) were microbiologically confirmed CRBSI. This subgroup analysis further translated to 1.49 CVAD infections per 1000 PN feeding days (13 true CVAD infections over 8695 PN feeding days). The types of CVADs that were associated with the 13 microbiologically confirmed CRBSIs included 2 double-lumen, pressure-injectable PICCs; 4 quadruple-lumen, chlorhexidine-impregnated central lines; 6 quadruple-lumen standard central lines; and 1 double-lumen Hickman catheter.

## Discussion

CVAD-related complications such as CRBSI, migration, a leak at site, and blockage are costly complications of hospital care for adult patients receiving PN. These complications are also associated with an increase in morbidity and mortality for the chronically ill patient and longer length of stay as a hospital inpatient. The aim of this study was to enhance the available evidence through analyzing CVAD outcomes associated with the administration of PN in general ward settings.

Overall, the results of this study demonstrate that only 13 of 629 CVADs (2.01%) had microbiologically confirmed CRBSI over 8695 PN feeding days. This translates to 1.49 CVAD infections per 1000 PN feeding days. This result is significantly lower than the evidence in the literature, which reported the incidence of CRBSIs in patients administered PN via CVAD as ranging from 4.4 to 5.7 per 1000 CVADs days.[19] Our study therefore contributes significantly to the paucity of evidence of CRBSI incidence rates in general ward settings. Despite the evidence in the literature reporting higher incidence than in our study, it does validate that although PN via CVAD is an independent risk factor for CRBSI and is associated with increased morbidity and mortality and prolonged hospitalizations, it is potentially a complication that can be minimized. With the increase in multiresistant microorganisms, our results are encouraging because they demonstrate that with diligent management of PN via CVADs, this can equate to low CRBSI incidence rates.

There are various factors that contribute to CRSBI in patients receiving PN via CVADs. Consistent with published evidence, a variety of microorganisms were responsible for the development of CRBSI in our study. Nosocomial infections from bacterial pathogens such as *S epidermidis* and *K pneumonia* were the most common causative agents, which is consistent with the findings reported several other studies.[20,21]

Although key international organizations recommend that a dedicated lumen of a tunneled CVAD should be the exclusive route for administering PN,[22,23] other researchers

**Table 3.** Reasons for Removal of CVAD.

| | Reasons for Nonroutine Removal | | |
|---|---|---|---|
| | All Nonroutinely Removed Catheters (n = 104) | All Potential Infective-Complication Removals (n = 71) | Infected Catheters' Reasons for Removal (n = 18) |
| Frequency (%) | | | |
| Catheter-related sepsis (suspected CVAD infection) | 38 (36.54%) | 38 (53.52%) | 6 (33.33%) |
| Non–catheter-related fever | 30 (28.85%) | 30 (42.25%) | 6 (33.33%) |
| Patient removal | 11 (10.58%) | — | — |
| Leak at site | 6 (5.77%) | — | — |
| Thrombus | 4 (3.85%) | — | — |
| Line migration | 4 (3.85%) | — | — |
| Accidental removal | 3 (2.88%) | — | — |
| Catheter blockage | 2 (1.92%) | — | — |
| Generalized patient sepsis | 2 (1.92%) | 2 (2.82%) | 4 (22.22%) |
| Arrhythmia | 1 (0.96%) | — | — |
| Pain and swelling at Hickman site | 1 (0.96%) | — | — |
| Redness at site | 1 (0.96%) | 1 (1.41%) | 1 (5.56%) |
| Catheter fracture | 1 (0.96%) | — | — |
| Not changed/decontaminated | — | — | 1 (5.56%) |

CVAD, central venous access device.

have proposed the early removal of surgical multilumen catheters and the insertion of single-lumen CVADs solely for PN administration, in an attempt to minimize nosocomial CRBSIs.[24] However, such approaches are logistically challenging for patient cohorts who require multilumen CVADs for complex intravenous therapies including the administration of fluids, blood products, medication, and hemodynamic monitoring. As a result, multilumen CVADs are left in situ in our hospital setting until completion of therapy, unless there is a clear, demonstrated indication necessitating removal or change. In many cases, an original perioperative quadruple-lumen CVAD will serve the patient through ICU, through the wards, and on to completion of PN therapy without incident. Similarly, a systematic review by Gavin et al (2018)[25] concluded that there is insufficient evidence to establish an association between risk of CRBSIs and the type of catheter used. Therefore, the positive findings presented here provide evidence to suggest that choice of device should individualized to the patients' needs and total infusion requirements. Our recommendation based on the results of our findings is that in the absence of complication, multilumen catheters should not be routinely changed to single-lumen CVADs, in an attempt to minimize nosocomial CRBSIs.

Because of anecdotal evidence from anesthetists reporting an increase in chlorhexidine anaphylaxis incidence upon anesthetic induction, a decision was made for perioperative insertion of CVADs to revert to use of standard, nonimpregnated devices in the study hospital. Routine anesthetic-inserted CVADs were no longer antimicrobial impregnated. However, a limited number of chlorhexidine-impregnated catheters were used after the transition date to use up existing stock. Changes in the CVAD infection rate and the type of microorganisms colonized were anticipated. Nevertheless, a surprising feature of our results was that there was no increase in colonization or CRBSI rates associated with the use of antimicrobial-impregnated CVADs. These results do not provide evidence to support the effectiveness of the use of antimicrobial-impregnated CVADs. However, future studies investigating the impact of other technological approaches and practices, such as the use of chlorhexidine-impregnated site dressings or antimicrobial CVADs, are necessary to provide robust evidence.

There are multiple key nursing implications to consider when interpreting results from our study. First, our patient cohort had CVADS inserted by a dedicated nutrition-support nursing service that had been established longer than 20 years in a principal referral and teaching hospital. The dedicated team practiced within well-established, evidence-based hospital guidelines, with a thorough understanding of best clinical practice for general ward–administered PN, together with an awareness of potential complications and clinical practices. This is an important consideration because evidence suggests that workforce issues, such as high turnover of the nursing team and inexperienced nursing teams, are associated with a significant increase in CRBSIs.[26] Furthermore, as supported by evidence from the literature, dedicated nurse-led CVAD

**Table 4.** Microorganisms Isolated From Culture-Positive and CRBSI CVADs.

| Microorganisms Isolated | Culture-Positive CVADs | CRBSI CVADs |
|---|---|---|
| Gram-positive bacteria | | |
| *Enterococcus faecalis* | 1 | 1 |
| *Staphylococcus capitis* | 1 | 1 |
| *S epidermidis* | 5 | 3 |
| *Staphylococcus hominis* | 2 | 1 |
| Gram-negative bacteria | | |
| *Escherichia coli* | 1 | 0 |
| *K pneumoniae* | 3 | 3 |
| *Pseudomonas aeruginosa* | 1 | 1 |
| *Serratia marcescens* | 2 | 1 |
| *Staphylococcus haemolyticus* | 1 | 1 |
| Yeast and fungi | | |
| Candida | 3 | 1 |
| Total number of organisms | 20 | 13 |

CRBSI, catheter-related bloodstream infection; CVAD, central venous access device.

teams provide ongoing consistency of clinical nursing practice and support for nursing and medical staff to ensure that robust clinical policy drives best practice.[27] Secondly, there is extensive experience and knowledge of medical and nursing staff in understanding the patient's anticipated postoperative vascular access needs at this hospital. Initial vascular access device selection aims to meet the patient's entire inpatient hospital vascular access needs, and is not limited to the immediate preoperative or critical care period. This in turn reduces unnecessary catheter replacements.

The advantages of inserting CVADs in general ward areas include a significant cost savings, as general anesthetic and operating facilities are not required.[28] Current practices related to CVAD type, dressing types, dressing frequency, vigilant clinical evaluation and assessment of the catheter site, cleaning solutions, administration set types, and frequency of change that have been reported to be effective in optimizing CVAD outcomes in critical care settings[29] are further supported by the current study. The most imperative aspect in the prevention of CRBSIs is a dedicated and highly trained nursing team that uses multiple interventions to minimize CRBSIs. The nursing staff involved in the management of PN via CVADs can prevent CRSBIs through strict adherence to policies and guidelines, maintaining asepsis, adequate hand hygiene, and training and education sessions to update their skills and knowledge. It must be noted that the barrier to insertion of CVAD for PN management in the general ward setting is that in the study hospital, the PN management is a consultative service, and there have been instances when CVADs are removed by individual medical or surgical teams because of suspected infection, without referral to the dedicated PN service. Further studies on educational interventions and their effect on length of hospitalizations and rate of CRBSIs are required. Evidence has also suggested that interventions such as routine national surveillance of CRBSI would enable variations in practice to be identified, leading to improved patient outcomes and a reduction in CRBSIs.[25]

The main limitation of our study is that it was conducted in a single center. This could be addressed in the future by conducting a multicenter research study to provide more robust evidence. A further limitation is that it was a retrospective study design, which relied on accurate labeling of blood cultures for database creation and accurate documentation, which may introduce bias into our results. A multivariate analysis of the factors associated with an increased risk of CRBSI would have provided the opportunity to gather a more realistic picture that nursing management led to safer PN use and a reduction in CRBSIs, rather than a reliance on single variable. Furthermore, the small number of CVAD-related complications limited the ability to undertake a detailed subgroup analysis based on variables such as age, site inserted, or clinical specialty. Additionally, CVAD removal criteria over the study period may have changed. These issues may be addressed in future prospective studies using more comprehensive patient-level data collection, stricter diagnostic criteria, and observation of clinical practices. Nevertheless, clinical practices for the insertion, care, and maintenance of CVADs were standardized across all the general ward areas. Data related to the administration of PN were entered prospectively by the nursing team. The positive patient outcomes related to CVAD complications provide strong evidence for the feasibility and adoption of such a cost-effective, evidence-based approach for a large principal referral and teaching hospital. Our results are based on data for PN-associated CVADs that were maintained in general ward settings, and there are limited studies that have been conducted outside of critical care settings. A wide variation in studies analyzing CRSBI in patients administered PN means that there is no consistency in terms of clinical setting, the type of CVAD, patient risk factors, and the varying terminology to describe colonized and infected CVADs. This is a significant limitation because the etiology of CRBSI depends on these important factors.

Despite these reported limitations, our study also highlights important strengths. The major strength of our study is that data were collected prospectively from a large sample of patients receiving PN in the general ward setting. Furthermore, the diagnostic microbiological criteria for CRBSI diagnosis were standardized throughout the study, which provided consistency. It should be noted that the facility where this study was conducted serves as a major specialty service for cytoreductive surgery with intraperitoneal chemotherapy. Therefore, our findings are encouraging, considering that a significant proportion of the patient cohort captured in our study were peritonectomy patients.

These patients necessitate complex care requiring CVADs for the delivery of concurrent intravenous infusions. Our study does, however, demonstrate the importance of continued vigilance to reduce CRBSI through prevention methods and well-established, evidence-based hospital guidelines.

## Conclusion

This study reviewed outcomes of patients who had catheters inserted by a dedicated team, including a nurse-led service over a 3-year period. The findings of our study were based on 629 CVADs that were managed in general ward settings for the administration of PN. These inserted CVADs in our study experienced complications at rates that are equal to or better than those previously published within general ward settings. This result contributes to the evidence in this field, suggesting that effective nursing care, supported by appropriate clinical policy and procedural standardization and by dedicated educational interventions, has the potential to achieve zero CVAD complications for patients receiving PN in general ward settings. This is imperative in an era of increasing healthcare costs and drug-resistant hospital infections. Therefore, further research will provide the necessary evidence to inform the appropriate management of patients with CVADs in general ward settings to reduce CRBSI.

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### Statement of Authorship

I. Martincich,K. Cini, and S. Lapkin equally contributed to the conception and design of the research; R. Fernandez and H. Lord contributed to the design of the research; I. Martinicich, K. Cini, and S. Lapkin contributed to the acquisition and analysis of the data; S. Lapkin and R. Fernandez contributed to the interpretation of the data; and I. Martincich, K. Cini, S. Lapkin, R. Fernandez and H. Lord drafted the manuscript. All authors critically revised the manuscript, agree to be fully accountable for ensuring the integrity and accuracy of the work, and read and approved the final manuscript.

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