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The Impact of Bundled Nursing Interventions on Preventing Central Venous Catheter-Related Bloodstream Infections

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Abstract

Objective: To investigate the effect of bundled nursing interventions on preventing central venous catheter (CVC)-related bloodstream infections (CRBSIs), aiming to reduce infection rates and improve patient safety. **Methods:** This retrospective (non-randomized) in nature, which may limit its causal inference study analyzed 200 patients who underwent CVC placement at a tertiary hospital between January 2022 and December 2023. Patients were randomly divided into a control group (n = 100) receiving standard care and an experimental group (n = 100) receiving bundled nursing interventions in addition to standard care. These interventions included strict aseptic techniques, standardized catheter maintenance, patient education, and collaborative management among healthcare providers. The CRBSI incidence and nursing outcomes were compared between the two groups. **Results:** The experimental group had a markedly lower CRBSI incidence compared to the control group. Patient satisfaction with nursing care was notably higher in the experimental group. Additionally, the experimental group experienced shorter hospital stays and lower antibiotic consumption compared to the control group. **Conclusion:** Bundled nursing interventions effectively reduce the incidence of CVC-related bloodstream infections, enhance nursing quality, and improve patient satisfaction, demonstrating substantial clinical value.

Keywords

Bundled Nursing, Central Venous Catheter, Bloodstream Infection, Nursing Intervention, Prevention

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1. Introduction

Central venous catheters (CVCs) are widely used in intensive care, chemotherapy, and long-term intravenous therapy. However, CVC-related bloodstream infections (CRBSIs) are serious complications that increase hospitalization duration and medical costs and can lead to severe infections or even be life-threatening. Therefore, effective prevention of CRBSI is a critical issue in clinical nursing.

In recent years, bundled nursing interventions have emerged as a systematic, standardized, and targeted strategy to prevent CRBSI. This study aims to explore the clinical effectiveness of bundled nursing interventions in reducing CRBSI incidence.

2. Methods

2.1. Subjects

This study selected a total of 200 patients who underwent central venous catheter (CVC) placement at a tertiary hospital between January 2022 and December 2023. Patients were randomly assigned using a computerized random number table into a control group (n = 100) and an experimental group (n = 100).

To ensure a representative and consistent sample, specific inclusion and exclusion criteria were established.

Inclusion Criteria:

1) Age ≥ 18 years;

2) Undergoing CVC placement with an expected duration of ≥7 days;

3) No diagnosis of severe immunodeficiency or hematologic malignancy during the study period;

4) No history of central line-associated bloodstream infections (CLABSIs) or current anti-infective therapy;

5) Provided signed informed consent to participate in the study.

Exclusion Criteria:

1) History of severe systemic infectious diseases, such as sepsis, HIV, or tuberculosis;

2) Withdrawal from treatment or lost to follow-up during the study period;

3) Presence of pre-existing local infection at the catheter insertion site;

4) High-risk comorbidities, such as uncontrolled diabetes, chronic renal failure, or advanced cancer;

5) Cognitive impairment or communication barriers that could affect compliance.

Baseline characteristics such as age, sex, underlying diseases, catheterization site, and catheter dwell time were recorded and compared between the two groups to ensure no significant differences at baseline.

2.2. Study Design

This study employed a randomized controlled trial (RCT) design. The control group received routine nursing care, which included basic hygiene measures, standard

catheter maintenance, and general observation. In contrast, the experimental group received bundled nursing interventions in addition to standard care. These interventions were comprehensive, evidence-based measures aimed at reducing the incidence of catheter-related bloodstream infections (CRBSIs).

The bundled intervention protocol is comprised of five core components and is implemented through a multidisciplinary approach.

2.2.1. Strengthening Aseptic Techniques

1) Strict Hand Hygiene Management:

- All nursing personnel performed six-step handwashing using antiseptic soap or alcohol-based hand rub before and after catheter-related procedures.
- Alcohol-based hand sanitizers were placed at all care stations to facilitate rapid disinfection.

2) Aseptic Operation Standards:

- Maximum sterile barrier precautions were adopted during catheter insertion, including the use of sterile gloves, masks, gowns, and large sterile drapes.
- The skin at the insertion site was disinfected with chlorhexidine gluconate in alcohol solution for at least 30 seconds and allowed to dry completely.
- Sterile, single-use CVC kits were used, and catheter insertion strictly followed the hospital's standard operating procedures (SOPs).

2.2.2. Standardizing Catheter Maintenance

1) Dressing Management:

- Transparent semipermeable dressings were replaced every 7 days or sooner if soiled, loose, or moisture-compromised.
- Gauze dressings were replaced every 48 hours, ensuring a clean and dry environment around the catheter site.

2) Catheter Flushing and Locking:

- Positive-pressure flushing techniques were employed using saline or heparin lock solutions to prevent thrombotic occlusion.
- Line connections and disconnections were minimized, and closed-system devices were utilized where possible.

3) Catheter Site Monitoring:

- Catheter insertion sites were inspected daily for redness, swelling, exudate, or tenderness.
- A designated infection control nurse documented and reported any signs of local or systemic infection promptly.

2.2.3. Patient Education

1) Health Literacy and Risk Communication:

- Patients and their families received CRBSI-related education via printed materials, bedside instruction, and educational videos.
- Teaching focused on recognizing early signs of infection, hand hygiene, and safe handling of the catheter.

2) Individualized Care Plans:

- Nursing staff tailored interventions for patients with special conditions, such as diabetes or low immunity, providing additional guidance on glycemic control and skin care.
- For long-term catheter users, telephone or online follow-up was conducted post-discharge to reinforce compliance and monitor for complications.

2.2.4. Collaborative Management among Healthcare Providers

1) Formation of a CVC Care Team:

- A multidisciplinary team was formed, consisting of ICU physicians, infection control specialists, clinical pharmacists, and senior nurses.
- The team conducted weekly rounds and jointly developed individualized CVC care plans for high-risk patients.

2) Continuous Professional Development:

- Monthly in-service training was conducted to ensure up-to-date knowledge of aseptic technique, catheter care, and infection control.
- Simulation training and peer assessments were incorporated to enhance practical skills and promote a culture of safety.

2.2.5. Antimicrobial Management

1) Rational Antibiotic Usage:

- Antibiotics were administered only when CRBSI was clinically suspected or confirmed through blood cultures, based on hospital antibiotic stewardship protocols.
- Empirical antibiotic therapy was adjusted promptly upon receiving culture sensitivity results.

2) Surveillance of Antimicrobial Resistance:

- Pathogen data from CRBSI cases were reviewed quarterly to track resistance patterns, such as MRSA and ESBL-producing organisms.
- Feedback was provided to clinical teams to support evidence-based updates to empirical therapy guidelines.

3. Results

3.1. Comparison of CRBSI Incidence

The incidence of central venous catheter-related bloodstream infections (CRBSIs) was significantly lower in the experimental group (see Table 1) compared to the control group. Specifically, only 3 patients (3%) in the experimental group developed CRBSI, whereas 12 patients (12%) in the control group experienced CRBSI. The difference in infection rates was statistically significant ($P < 0.05$), indicating that the implementation of bundled nursing interventions effectively reduced the risk of bloodstream infections associated with central venous catheters.

This reduction in infection incidence not only reflects improved adherence to aseptic protocols but also underscores the potential of standardized nursing strategies to minimize preventable complications.

Table 1. Comparison of CRBSI incidence between groups.

Group	Number of Cases (n)	CRBSI Cases (n)	CRBSI Incidence (%)
Control Group	100	12	12.0
Experimental Group	100	3	3.0

Note: CRBSI = Central venous catheter-related bloodstream infection. The incidence rate was significantly lower in the experimental group (3.0%) compared to the control group (12.0%), indicating the effectiveness of bundled nursing interventions ($P < 0.05$).

3.2. Comparison of Nursing Satisfaction

Nursing satisfaction was assessed using a standardized patient satisfaction questionnaire, which included items on communication, technical skills, responsiveness, and perceived safety of care. The experimental group reported significantly higher satisfaction scores across all dimensions compared to the control group ($P < 0.05$).

This improvement can be attributed to better nurse-patient communication, enhanced education regarding catheter care, and the professional and coordinated appearance of the interdisciplinary nursing team. The involvement of patients in care decisions and consistent feedback mechanisms also contributed to increased satisfaction levels.

3.3. Comparison of Hospital Stay and Antibiotic Use

The average length of hospital stay for patients in the experimental group was 7.2 ± 1.5 days (see Table 2), compared to 9.8 ± 2.1 days in the control group. Similarly, antibiotic usage was reduced both in duration and total dosage among patients receiving bundled interventions. The mean duration of antibiotic therapy was 4.1 ± 1.0 days in the experimental group versus 6.3 ± 1.7 days in the control group ($P < 0.05$ for both comparisons).

Table 2. Comparison of hospitalization and antibiotic use.

Outcome	Control Group (Mean ± SD)	Experimental Group (Mean ± SD)	P-value
Length of hospital stay (days)	9.8 ± 2.1	7.2 ± 1.5	<0.05
Duration of antibiotic therapy (days)	6.3 ± 1.7	4.1 ± 1.0	<0.05

Note: Data are presented as mean ± standard deviation. Patients in the experimental group had significantly shorter hospital stays and lower duration of antibiotic therapy than those in the control group ($P < 0.05$), suggesting improved recovery and reduced complications due to bundled nursing interventions.

These differences suggest that the bundled intervention group achieved faster recovery, experienced fewer complications, and required less pharmacological intervention. Not only do these outcomes improve patient experience and clinical efficiency, but they also result in significant reductions in hospital resource utilization and treatment costs.

4. Discussion

The findings of this study confirm that the application of bundled nursing interventions significantly reduces the incidence of central venous catheter-related bloodstream infections (CRBSIs), improves patient satisfaction, shortens the length of hospital stays, and decreases the need for antibiotics. These results not only reflect improved clinical outcomes but also underscore the broader implications of nursing interventions for patient safety and healthcare system efficiency.

4.1. Effectiveness in Preventing CRBSI

The occurrence of CRBSI is intricately associated with the degree of adherence to aseptic techniques during catheter insertion and subsequent maintenance [1]. This study introduced a structured aseptic protocol encompassing thorough hand hygiene, the use of sterile barrier precautions, and standardized disinfection procedures. The significant reduction in infection rates in the experimental group demonstrates the clinical effectiveness of such strategies.

Notably, the results are consistent with prior multicenter studies that have shown up to 60% reductions in CRBSI incidence following the implementation of evidence-based care bundles [2]. The key to success lies in continuous training, strict supervision, and the creation of a culture of safety within the nursing team, all of which were emphasized in this study.

4.2. Improvement in Nursing Quality

Beyond infection control, bundled interventions contributed to the overall improvement of nursing quality [3]. By integrating individualized health education, rigorous catheter maintenance, and collaborative care models, nurses were empowered to deliver more consistent and high-quality care.

Patients and their families became more aware of infection risks and self-care responsibilities, which strengthened compliance and cooperation [4]. Furthermore, interdisciplinary collaboration allowed for the integration of expertise from infection control specialists, ICU physicians, and clinical pharmacists, which facilitated real-time decision-making and optimized patient outcomes.

These improvements reflect the increasing recognition of nurses' role not only as caregivers but as pivotal contributors to quality improvement and patient education initiatives.

4.3. Impact on Hospital Stay and Antibiotic Use

Hospital-acquired infections such as CRBSI often lead to prolonged hospitalization, increased antibiotic consumption, and elevated healthcare costs [5]. The findings of this study showed that patients in the bundled intervention group had significantly shorter hospital stays and required fewer antibiotics, reflecting faster recovery and fewer complications.

From a healthcare management perspective, this not only improves bed turnover efficiency but also contributes to antibiotic stewardship—a critical global health

priority given the rising threat of antimicrobial resistance (AMR) [6]. Therefore, bundled nursing practices indirectly support public health goals while benefiting individual patient care.

4.4. Study Limitations and Future Directions

While the results of this study are promising, several limitations should be acknowledged:

1) Sample Size and Scope: The study was conducted at a single institution with a limited sample size, which may restrict the generalizability of findings. Larger, multicenter studies are needed to validate and extend these results across diverse clinical settings.

2) Study Design: Although randomized, elements of retrospective data collection may have introduced potential recall or selection bias. Future studies should adopt prospective, double-blinded, randomized controlled trials to enhance causal inference and eliminate confounding variables.

3) Heterogeneity of Patient Populations: The current intervention was standardized, but patients present varying risks depending on comorbidities, immune status, and catheter type. Future research should explore stratified or personalized intervention bundles that adjust to patient-specific risk profiles.

4) Long-term Outcomes: The study focused on short-term clinical indicators. Long-term follow-up regarding catheter patency, recurrence of infections, readmissions, and patient-reported outcomes (e.g. quality of life) would enrich the evaluation of bundled interventions.

5) Implementation Challenges: The success of bundled care depends heavily on institutional support, adequate staffing, continuous training, and monitoring. Further investigation is needed into the cost-effectiveness and sustainability of such interventions, particularly in resource-limited settings.

5. Conclusions

This study provides compelling evidence that bundled nursing interventions represent an effective and feasible strategy to reduce the incidence of CRBSI, improve patient safety, enhance satisfaction, and optimize healthcare resource utilization. The bundled approach—emphasizing aseptic technique, catheter care standardization, health education, team collaboration, and rational antibiotic use—demonstrated measurable improvements in clinical and nursing outcomes.

Given the increasing complexity of patient care and the rising burden of hospital-acquired infections, implementing bundled nursing strategies should be considered a best practice in CVC management. Clinical nursing departments are encouraged to institutionalize such protocols and support continuous quality improvement through training, audit, and interdisciplinary teamwork.

Future efforts should focus on the development of patient-centered, adaptive intervention models, as well as the integration of digital technologies (e.g. electronic alerts and infection surveillance systems) to enhance adherence and early detection.

In parallel, investment in nursing education and leadership development will be critical to sustain high-quality care practices.

Ultimately, bundled nursing interventions not only contribute to the reduction of CRBSI, but also symbolize a paradigm shift toward proactive, evidence-based, and collaborative nursing care in modern clinical practice.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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