

Preventive Interventions for Central Venous Catheter Infections in Intensive Care Units: A Systematic Literature Review

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Abstract—Catheter-related bloodstream infections are a major burden for healthcare and patients. Although infections of this type cannot be completely avoided, they can be reduced by taking preventive measures. The aim of this study is to review and analyze the existing literature on preventive interventions to prevent central venous catheters (CVC) infections. A systematic literature review was carried out. The international databases CINAHL, Medline, PubMed, and Web of Science were searched using the search strategy: "catheter-related infections" AND "intensive care units" AND "prevention" AND "central venous catheter." Articles that met the inclusion and exclusion criteria were included in the study. The literature search flow is illustrated by the PRISMA diagram. The descriptive research method was used to analyze the data. Out of 554 search results, 22 surveys were included in the final analysis. We identified seven relevant preventive measures to prevent CVC infections: washing the whole body with chlorhexidine gluconate (CHG) solution, disinfecting the CVC entry site with CHG solution, use of CHG or silver dressings, alcohol protective caps, CVC care education, selecting appropriate catheter and multicomponent care bundles. Both single interventions and multicomponent care bundles have been shown to be currently effective measures to prevent CVC infections in adult patients in the ICU. None of the measures identified stood out in terms of their effectiveness. Prevention work to reduce CVC infections in the ICU is a complex process that requires the simultaneous consideration of several factors.

Keywords—Central venous access, critically ill patients, hospital-acquired complications, prevention.

I. INTRODUCTION

CRITICALLY ill patients are admitted to intensive care units (ICU), where they receive advanced and complex care. The insertion and management of peripheral and central venous catheters is a mandatory part of the complex process of treating these patients [1]-[3]. Venous catheters are used to administer intravenous fluids, drugs, blood and blood products, parenteral nutrition, central venous pressure monitoring, blood draws for tests, hemodialysis, etc. [3]-[5].

In addition to all the advantages of venous catheters, there is also a risk of developing complications. There is a potential for occlusion, deep vein thrombosis and infection [6]. These complications are strongly associated with higher morbidity, mortality, longer hospitalization times and higher treatment costs [2]-[4]. The development of infections is considered one

of the more common and challenging complications, as it accounts for the vast majority of all bloodstream infections in ICU [6], [7]. Two terms are used to describe CVC-related bloodstream infections: catheter-related bloodstream infection (CRBSI) and central line-associated bloodstream infection (CLABSI) [1]. In both cases, the bloodstream infection appears with a patient who has had a CVC inserted, or has had one inserted in the last 48 hours, and has no other obvious cause of infection. In addition to the previous characteristics, the use of the term CRBSI requires a pathological diagnosis through positive blood cultures [1], [8].

Nursing plays an important role in preventing CVC-related bloodstream infections [8]. Nurses have complete autonomy when inserting peripheral venous catheters, choosing both the size of the cannula and the insertion site. They are involved in the insertion of the CVC, where their role is the psycho-physical preparation of the patient, the material and the room. Through systematic nursing care and careful handling of the vascular access, they contribute to preventing complications and the spread of infections [9].

Bloodstream infections associated with CVC are a major burden for healthcare systems and patients worldwide [4], [8], [10]-[12]. Although infections of this type cannot be completely avoided, the incidence can be significantly reduced through the correct implementation of preventive measures, internal controls and regular staff training [9]. Staff knowledge of the insertion and care of vascular catheters was found to be insufficient, suggesting a need for further education and research in the prevention of CVC-related bloodstream infections [4], [7], [12].

The number of new interventions, studies and tools is large, thanks to the focused efforts to tackle this issue. A literature review is needed to assess the effectiveness of improvements and compare them with each other. This would give the nursing profession insight into current evidence-based activities in the field of CVC infection prevention, which could be used to adapt and improve daily practices.

Aim and Objective

The aim of this study is to review and analyze the existing literature on preventive measures to avert CVC infections.

The objective of the study is to identify the most effective

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preventive measures for CVC care.

In line with our aims and objectives, we formulated the following research question: Which preventive measures are best to prevent CVC infections in adult patients in ICU?

II. METHODS

A systematic review of the scientific and professional literature on interventions for the prevention of CVC infections in the ICU was conducted.

Review Method

A descriptive research method was used, with a systematic review of domestic and foreign professional and scientific literature. The method chosen was used to demonstrate the most effective measures to prevent infections of central venous accesses in the ICU. Literature searches were performed in CINAHL, Medline, PubMed and Web of Science databases. The literature search was performed using a unique search string in October 2022, which was created using MeSH terms, free English terms, and Boolean AND (IN) operator. We used the following final unique search strategy: ("catheter related infections" AND "intensive care units" AND "prevention" AND "central venous catheter"). We included literature published from 2017 to 2022, as the last systematic review of the literature in this area was published in 2017 [3]. The literature search and review were further constrained by the inclusion and exclusion criteria shown in Table I.

TABLE I
INCLUSION AND EXCLUSION CRITERIA

Criteria	Inclusion criteria	Exclusion criteria
Theme	Prevention of CVC infections in the ICU.	Preventing infections of other types of catheters (peripheral venous catheter, arterial line, urinary catheter) in or out of the ICU.
Population	Patients in intensive care.	Patients outside the ICU.
Age of population	Adults.	Children aged 0 to 18 years.
Type of study	Original scientific articles, randomized clinical trials, meta-analyses.	Protocols, case studies.
Language	English.	
Publication date	2017 – 2022.	
Availability	No limitations.	

Review Results

Fig. 1 shows the literature search process according to the PRISMA methodology [1]. We identified 97 hits in CINAHL, 176 hits in Medline, 180 hits in PubMed and 101 hits in Web of Science. All hits were imported into Zotero [14] for easy organization, citation and referencing. After removing 113 duplicates, we screened 441 hits based on title and abstract, of which 394 were removed for thematic inappropriateness. In the next step, we screened 47 articles in full-text and retained 26 of them, after which we additionally excluded 4 articles on the basis of inadequate quality. Finally, 22 articles were included in the detailed literature analysis, as shown in Fig. 1.

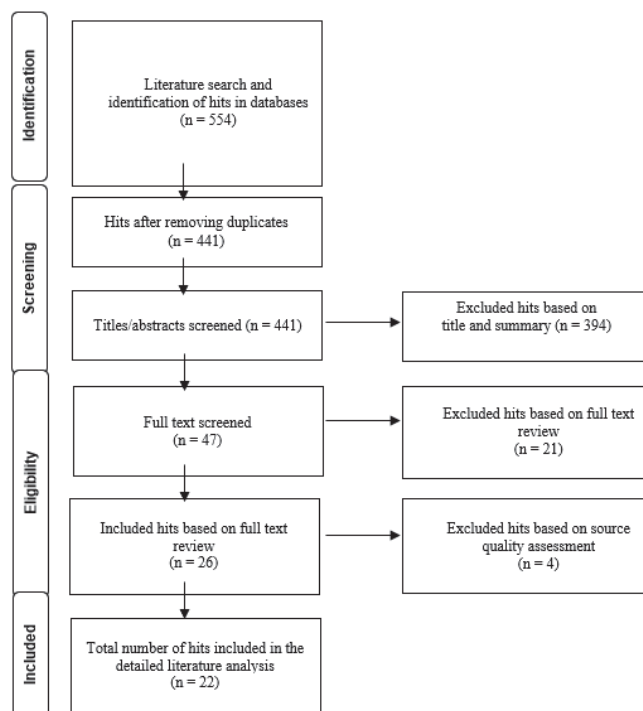


Fig. 1 PRISMA diagram of literature review process [13]

Assessment of the Quality of the Overview and Description of Data Processing

The selection of the literature was based on the relevance and quality of the articles selected. The quality of the articles was assessed using the Critical Appraisal Skills Programme (CASP) tools: the CASP Systematic Reviews Checklist, the CASP Randomized Controlled Trial Checklist, the CASP Cohort Study Checklist [15]. This allows for a critical assessment of the quality of a source based on the evaluation and interpretation of the evidence, systematically checking the reliability of the research, the results and the relevance of the content to the chosen topic. The articles were primarily separately evaluated by two researchers, with a third author involved in case of differences in the ratings for each study. Each article could be graded on one of four levels: inadequate, sufficient - C, good - B, excellent - A. If an article was graded as inadequate, it was excluded from further analysis. Table II shows the ranking of the included articles according to their quality in the last section.

III. RESULTS

In the final analysis, we included 22 studies investigating preventive measures to prevent CVC infections in adult patients in the ICU. Table II shows the main characteristics of the individual studies included in the final analysis. We have systematically focused on the type and purpose of the research, the intervention considered and the main findings. In addition, we have placed compliance with the PICO research question and the CASP research quality assessment in the last section. We have also ranked the research according to the hierarchy of evidence [16], with three studies placed to tier 1 [17]-[19], five to tier 2 [20]-[24], one survey to tier 4 [25], the remaining

research is classified as tier 3 [26]-[37].

TABLE II
A REVIEW OF THE KEY FINDINGS OF THE ARTICLES INCLUDED IN ANALYSIS

Reference	Study design	Study aim	Intervention	Main findings	PICO/CASP 0-3 / A-B+-
[26]	Retrospective, observational, quasi-experimental study	To assess the effect of multimodal measures on CLABSI rates and to analyze the effect of automatic notification of catheter days.	Use of protective measures - use of sterile headgear, mask, cap, sterile gloves and sterile gown; automatic notification of catheter days; daily assessment of the need for CVC; wash all body surfaces once daily with a non-woven cloth soaked in 2% CHG.	The number of days in the ICU, catheter days and CLABSI rate were reduced by multimodal measures including maximal precautions, automatic notification of catheter days and 2% CHG washout.	3/3 B
[27]	Observational quasi-experimental prospective study	To evaluate the effects of whole-body decolonization with 2% CHG on the incidence and type of CVC infections.	Disinfecting and skin cleansing wipes impregnated with 2% CHG.	Decolonization with 2% CHG reduced the overall incidence of healthcare-associated infections, especially CVC-related infections.	3/3 B
[17]	Meta-analysis of clinical trials	To assess whether the gradual introduction of CHG liners into the current CVC care bundle can further reduce the CLABSI rate.	Phasing in CHG dressings in addition to the existing CVC care bundle.	The gradual introduction of different CHG dressings over nine years, in addition to the continuous use of the CVC care bundle, gradually and significantly reduces the number of CLABSIs.	3/3 A
[20]	Prospective randomized study	To evaluate the effectiveness of educational interventions alone and in combination with the use of protective caps for needle-free fittings at CLABSI rates.	GAVECELT training kit; protective cap for needle-free nozzle, impregnated with 70% isopropyl alcohol.	Educational measures combined with the use of an impregnated protective cap resulted in a CLABSI rate of zero.	3/3 B+
[28]	Observational cohort study	To describe the results of the use of a new silver dressing for CVC protection, compared to CHG-impregnated dressings, in the prevention of CLABSI.	Silver dressing to protect CVK.	The use of a silver dressing to protect the CVC is associated with a significant reduction in CLABSI in adult patients in the ICU compared to patients receiving care with a CHG dressing.	3/3 B+
[21]	Randomized, prospective, double-blind study	Assess the impact of open and closed CVC systems on infection prevention.	Open and closed CVC systems.	Closed CVC systems, combined with adequate training of nurses, reduce CRBSIs.	3/3 A
[29]	Prospective quasi-experimental observational study	To determine the incidence of CLABSI and to identify the profile of micro-organisms causing the infection and the impact of the preventive measures implemented to reduce the CLABSI rate.	CVC insertion care bundle: hand hygiene before catheter insertion, optimal choice of catheter site, use of protective measures at insertion and skin preparation with CHG. CVC maintenance care bundle: daily assessment of CVC need, hand hygiene before and after all access maintenance procedures, alcohol disinfection of the catheter before each access, observation of the insertion entry site, dressing change using aseptic technique.	A significant reduction in CLABSI rates was observed after the introduction of a CVC care bundle comprising a number of prevention measures.	3/3 B+
[22]	Prospective, randomized, double-blind study	To investigate the safety and efficacy of the antibacterial catheter in terms of catheter colonization rates and bloodstream infections.	CVC antibacterial catheter; CVC without antibacterial coating.	Antibacterial CVC effectively reduced the incidence of CLABSI but not the rate of catheter colonization.	3/3 A
[30]	Quasi-experimental, non-randomized, clinical study	Assess the impact of the CVC care bundle in the 27 ICUs.	The care bundle for insertion included hand hygiene, use of protective measures at insertion, use of CHG for skin preparation and avoidance of the femoral veins as an access site. The maintenance care bundle included hand hygiene, correct dressing changes, aseptic technique for accessing and changing needleless catheters, and daily assessment of catheter need.	The introduction of the multidimensional care bundle for CVC has led to a significant reduction of 12.2% in the CLABSI rate in almost all participating ICUs, except surgical units.	3/3 B
[31]	Prospective, quasi-experimental, cross-sectional study	To compare the incidence of CRBSI and the growth of flora at the CVC insertion site between the use of 2% CHG and 10% povidone-iodo-alcohol (PVI) in the context of CVC care.	Use 2% CHG or 10% PVI to disinfect the entry point when setting up CVC.	When 2% CHG is used instead of 10% PVI, skin flora colonization at CVC insertion sites can be greatly reduced, and it may even lower the incidence of CRBSI in patients in the ICU.	3/3, B
[32]	Retrospective cohort study	To investigate the epidemiological characteristics of CLABSI and to assess whether peripherally inserted central venous catheters (PICCs) are	Position of the insertion site; type of catheter (CVC and PICC).	CVCs are associated with a higher risk of CLABSI compared to PICC.	3/3, B+

Reference	Study design	Study aim	Intervention	Main findings	PICO/CASP 0-3 / A-B+/-
[33]	Quasi-experimental, non-randomized, clinical study	associated with a protective effect for CLABSI. To evaluate the effect of alcohol-impregnated CVK protective caps on the reduction of CLABSI incidence in the burn ICU.	Alcohol-impregnated caps to protect the CVC.	The use of alcohol-impregnated protective caps can potentially reduce the incidence of CLABSI.	3/3 B-
[34]	Quasi-experimental, non-randomized, clinical study	To investigate whether an education program aimed at health workers has led to a significant change in infection rates and trends.	An educational program covering hand hygiene and standard precautions to prevent infections.	An educational program that focused on general good practice in infection control rather than CVC care bundles reduced the CRBSI rate, although the improvement was not sustained.	3/3, B
[18]	Systematic literature review and meta-analysis	To evaluate the effectiveness of CHG coatings for the prevention of CRBSI.	CHG CVC dressings.	CHG wraps prevent CRBSI in adults with short-lived CVCs, including patients with oncohaematological diseases. CHG dressings can reduce entry site infections and catheter colonization in long-term CVC.	3/3, A
[35]	Quasi-experimental observational study	To analyze the effect of daily CHG washing in patients in the ICU on the incidence of CLABSI.	Daily washing with CHG.	The introduction of daily CHG washing resulted in a reduction in the incidence of CLABSI in the ICU.	3/3, B+
[36]	Quasi-experimental observational study	Determine whether the training program can reduce the level of CRBSI in the ICU.	CLABSI Incidence Reduction Training Program: 30-minute video introduction, 120-minute lecture with numerous practical training sessions, test, posters, safety checklists and feedback from the Infection Control Committee.	A program aimed at educating healthcare workers about CRBSI prevention has led to a dramatic reduction in the rate of primary bloodstream infections.	3/3, B
[19]	Meta-analysis	To evaluate the efficacy of chlorhexidine and povidone solutions as skin disinfectants in CVC care.	Chlorhexidine solutions; povidone solution.	Chlorhexidine CVC care solution can significantly reduce the rate of CRBSI and catheter colonization compared to povidone solution. The disinfecting effect of chlorhexidine-alcohol is better than that of other solutions.	3/3, A
[23]	Randomized control study	Comparison of standard CVC protective caps with alcohol-containing caps in terms of CLABSI prevention	Alcohol-impregnated protective caps for the needle-free CVC nozzle	The findings suggest that protective alcohol caps for needle-free fittings are effective in preventing CLABSI.	3/3, A
[38]	Quasi-experimental observational study	To test whether the introduction of CHG washing throughout the ICU instead of triclosan would have an impact on the CLABSI rate.	Washing with CHG.	Routine washing with CHG versus triclosan did not affect the CLABSI rate or the positive blood cultures obtained in the ICU. However, it has significantly reduced the incidence of MRSA.	3/3, B+
[25]	Cohort study	To assess the CLABSI rate following the introduction of a care bundle for CVC deployment and maintenance.	CVC insertion and care bundle: hand hygiene before insertion and during handling of CVCs, aseptic insertion technique, use of protective measures, avoidance of femoral veins, use of CVCs with antimicrobial coating, use of CVCs with a lower lumen count, use of sterile devices, change of dirty, soaked and peeled liners, standardized weekly changing of liners, daily CHG wash for all CVC patients, protective alcohol caps for needle-free adapter, daily assessment of CVC need, education of medical staff on correct insertion and maintenance of CVC, root cause analysis and re-education for each CLABSI case, avoidance of blood cultures from CVC.	After the introduction of the CVC insertion and maintenance care bundle, the results showed a reduction in the CLABSI rate.	3/3, B
[37]	Cohort, quasi-experimental study	Determine whether the introduction of a checklist reduces the CLABSI rate.	Checklist of hygiene standards: hand hygiene, use of protective measures, sterile disinfection of the entry site, avoidance of femoral veins, clear indications for CVC.	The introduction of a checklist to improve adherence to hygiene standards in CVC insertion has significantly reduced the incidence of infections.	3/3, B
[24]	Multicenter randomized control study	To compare the efficacy of three antiseptic solutions: 0.5% and 1.0% CHG and 10% PVI to prevent CVC colonization.	0.5% alcoholic CHG; 1.0% alcoholic CHG; 10% water PVI.	Both 0.5% and 1.0% alcoholic CHG are better than 10% aqueous PVI at preventing CVC colonization.	3/3, A

The analysis identified seven effective preventive measures for CVC infections. Five studies [25], [26], [29], [30], [37], identified CVC care bundles that differed from one another as an effective intervention. All care bundles included hand hygiene, use of protective measures and use of CHG solutions for insertion or entry site care. Individual additional specific actions of the care bundles are listed in Table II under the intervention section.

Research has identified the use of CHG solutions as an effective preventive measure for daily washing of the whole body [27], [35], [38] or for disinfection of the point of entry of the CVC [19], [24], [31].

Entry site dressings with CVC have also been shown to be effective in preventing CVC infection [17], [18] or silver [28]. The use of alcohol-soaked protective caps for needle-free use is also effective in reducing the incidence of CVC infections [23], [33]. Reference [20] found alcohol-soaked protective caps to be effective in combination with the use of additional educational content. On their own, various educational contents (hand hygiene, standard precautions, video content, lectures, posters, etc.) have been identified as an effective preventive measure in two other studies [34], [36].

The incidence of CLABSI and CRBSI can also be influenced by the correct choice of the location or type of CVC and the properties of the CVC itself. CVC infections have been shown to occur more with CVCs than with PICC catheters [32], and less with closed systems [21] and antibacterial-coated CVCs [22].

IV. DISCUSSION

The answer to the research question is complex, as it is not possible to single out one sole most important intervention for the prevention of CVC infections. Individual interventions (washing the whole body with CHG solution, disinfecting the CVC entry site with CHG solution, use of CHG or silver liners, alcohol protective caps, CVC care education, selection of appropriate catheter), as well as multicomponent care bundles have been shown to be effective measures to prevent CVC infections in adult patients in the ICU at the moment.

Regarding efficacy, none of the listed measures stood out. None of the studies analyzed compared all measures with each other. Other research [1], [3], which looked at the effectiveness of several preventive measures together, came to similar conclusions. In line with our findings, different CVC care bundles, educational programs, catheter characteristics, protective stoppers, and the use of CHG solutions for washing or in dressings were identified as effective.

Trends in research and healthcare settings indicate the popularity of implementing care bundles for CVC. They differ in their component precautions, but all have in common hand hygiene, the use of protective measures and the use of CHG solutions for insertion or entry site care [25], [26], [29], [30], [37]. Consistent with our findings, other studies [39], [40] identified multicomponent CVC care bundles as effective in preventing infections. Individual studies [10], [12], [41]-[43] identify certain limitations in their implementation and adherence, despite the effectiveness of the bundles. To achieve

good outcomes with the care bundles, all measures in each bundle need to be introduced and implemented [10], [41], [43]. Before implementing a specific CVC care bundle, its selection or design should be checked for compatibility and appropriateness with the specific health facility or department and the way it works [42]. Before implementing a new care pathway, healthcare staff need to be prepared and trained to implement the individual interventions involved [12], [41].

Education programs found in other research [1], [43]-[45] have shown to be effective in preventing CVC infections. To be effective, training programs need to include a variety of components ranging from content (hand washing, use of protective measures, use of CHG solutions, choice of entry point, etc.) to teaching strategies (classical lecture, video content, posters, training in a simulated environment, etc.) [1], [45]. Literature [43] notes that training needs to be delivered and planned according to the needs and characteristics of the individual department and learners. To achieve lasting effects, education must be continuous [44], [45]. Even in one of the studies included in the analysis, one-off education only achieved results that were not sustainable [34].

CHG washing has also been recommended for the prevention of CVC infections based on the research work of other authors [46]-[48]. It should be noted, however, that CHG solutions should only be used on skin that is not damaged, as even when the integrity of the skin is preserved, irritation or even allergies may occur and are discouraged [47]. In relation to the use of CHG solutions, a randomized clinical study [49] found that CHG dressings are an effective measure to reduce CVC infections. In contrast, a study [50] found that CHG coatings do not reduce the incidence of CLABSI. However, they do make nurses' jobs easier, as they need to be changed less often.

Open CVC systems are also a risk factor for CLABSI. Alcohol caps are used to prevent this factor. The research carried out [1], [51]-[54] also notes the benefits of using protective alcohol caps. In addition, a study [53] found that the use of these reduces the cost of treatment. Although there is a large body of literature supporting the prevention of CLABSI through the use of protective alcohol caps, some conclude that these are not effective without other protective measures [55], [56].

As mentioned in the results, the choice of a catheter with the right properties is also very important for the prevention of CVC infections. With advances in medical devices, different types of catheters, antibacterial-coated CVCs and open or closed CVC systems are now available. Of all the CVC variants, there is the most research [1], [57], [58] which supports the use of antibacterial-coated CVCs to prevent CLABSI. Two studies [2], [59] conclude that the use of antibacterial-coated CVCs as a stand-alone intervention does not reduce the incidence of CVC infections.

The findings of the survey should be interpreted with caution due to implementation limitations. Only certain databases were reviewed, only English-language surveys were included, and the surveys measured different outcomes in different sample sizes. In our research, we took a broad approach, looking for the single most effective preventive measure among many. Given

that several simultaneous measures are needed to reduce CVC infections, it would be worthwhile to investigate each one separately to see if it is effective.

Through a literature review, we demonstrated that preventative efforts to lower CVC infections in the ICU are a complicated process that demands the joint evaluation of a number of parameters. We have shown that different CVC care bundles, addressing the topic from different perspectives and with multiple interventions in parallel, are best suited to achieve a reduction in the incidence of CLABSI.

In future research, it would be worthwhile to focus on empirical research on each of these measures. A systematic literature review with meta-analysis of CVC care bundles would also be advisable. This would allow us to qualitatively evaluate the best CVC care bundles and design the most appropriate one that would represent universal guidelines for the clinical setting and would require minimal adaptations to cover specifics.

V.CONCLUSION

The ICU is a challenging environment where various complications often arise. CVC infection is one of them, and is a major burden on the health system. In our study, we identified several different measures for effective prevention, such as: washing the whole body with CHG solution, disinfecting the CVC entry site with CHG solution, use of CHG or silver liners, alcohol protective caps, CVC care education, selection of an appropriate catheter, and CVC care bundles consisting of different preventive measures. Given that the different care bundles include several individual interventions, it would be reasonable to first investigate the effectiveness of individual preventive interventions and then combine the proven effective ones into a new care bundle. The research could be used to update current practice and help improve patient care, the working environment and cost-effectiveness. Through a systematic literature review, we have provided the nursing profession with insights into current evidence-based practices in the prevention of CVC infections. The findings can potentially improve their daily practice and make their work easier. This would also ensure better quality of care and higher patient satisfaction.

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