

Review Article

The effect of silver-impregnated catheters on catheter colonization and catheter-related bloodstream infection: a comparison between silver-impregnated and standard catheter

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ABSTRACT

The use of antimicrobial central catheter is common in clinical practice to prevent catheter colonization, therefore preventing catheter-related blood stream infection (CRBSI). This paper aims to evaluate evidence from the literature in order to illustrate the effectiveness of one of the most common antimicrobial central catheters, chlorhexidine/silver sulfadiazine central venous catheter, in the prevention of bacterial colonization and CRBSI. Several studies have been selected including randomized control trails (RCTs), meta-analysis and systematic review. The seven RCTs included a total number of 2346 catheters. The patients were either assigned to an intervention group (silver-impregnated central venous catheter) or a control group (standard catheter). These studies were conducted in the USA, Europe, Australia and Brazil from 2004 until 2012. The results revealed that there was a discrepancy in the effectiveness of using silver-impregnated central venous catheter in prevention of catheter colonization and catheter-related bloodstream infection. More recent randomized studies are needed to solve this discrepancy, with a focus on following of infection control measures as the golden standard to prevent colonization and reduction of CRBSI.

Keywords: Catheter related infection, Chlorhexidine/silver sulfadiazine, Colonization, Infection control, Intensive care

INTRODUCTION

In the last decades, venous access through specific catheter insertion has become a renowned procedure in both inpatient and outpatient settings, for many purposes, including medication administration, renal therapy, hemodynamic monitoring, and blood sampling.^{1,2}

Central venous catheters (CVCs) are inserted through a major vein (e.g. internal jugular, subclavian, and femoral).³ This practice unfortunately can introduce the bloodstream to microorganism leading to bloodstream infection (BSI).¹ Catheter-related bloodstream infection (CRBSI) can be defined as laboratory confirmed blood culture without another specific source of infection with a

central line in place for 48 hours before the onset of infection. Catheter colonization can be defined as a quantitative culture tip yielding more than 1000 colony-forming units per mL or a semi quantitative culture tip yielding >15 colony-forming units per mL.^{4,5}

The risk factors for catheter-related bloodstream infection includes firstly patient-related factors such as severity of disease and compromised integrity of patients' skin, secondly, catheter-related factors such as type and the properties of the catheter, thirdly, operator-related factors such as the insertion of the catheter and its maintenance.¹

CRBSI remains one of the most dangerous complications of central venous access and it is considered as an

extremely serious hospital acquired infection with substantial mortality and morbidity in the intensive care units. In addition, those infections are not only hazardous to patients, but they are also expensive to treat.⁶

The management and prevention of CRBSI have become a main concern for health care providers.¹ Moreover, the Center of Disease Control and Prevention has published a well-organized and well-recognized recommendations regarding the insertion and maintenance of central lines to minimize CRBSI which can be summarized briefly in the following points.⁵

- Educate health care personnel about indications for central venous catheter, as well as the appropriate procedure for both insertion and maintenance. Moreover, the application of proper infection control measures to prevent catheter –related infection.
- Use of personal protective equipment including not only sterile gloves during insertion but also sterile gown, mask head cap and full body drape.
- Prepare the skin for insertion by using antiseptic solution the antiseptic solution should be permitted to dry before insertion.
- Use of sterile gauze or sterile transparent dressing to cover the insertion site.
- No need to administer systemic antibiotic prophylaxis before insertion to prevent catheter colonization.
- Generally, do not use anticoagulant to minimize the risk of catheter related infection.
- Use an antimicrobial central venous catheter in patients who need the catheter to stay in place for more than 5 days.

Reducing the number of CRBSI is fundamental to health care providers (HCPs) in clinical practice, different types of central venous catheters are being used, for example, heparin-coated catheter, antimicrobial/antiseptic impregnated catheters (e.g. minocycline/rifampin) and first and second generation of chlorhexidine/silver sulfadiazine (CH-SS). For example the first generation has external surface impregnated while the second generation has both external and internal surfaces impregnated.^{5,7-9}

The use of silver for treatment and preventive purposes of infection dates back to at least 4000 BC due its antimicrobial and bactericidal activities.¹⁰ Khare et al have found that the rate of colonization at silver-impregnated catheter tip was lower than stander catheter, specifically, a lower rate of colonization of coagulase negative staphylococci on the other hand the effect on CR-BSI was not statistically significant.¹¹

In a meta-analysis by Chen et al in 2014, involving 1440 patients who received standard central venous catheter (CVC) and 1414 who received silver-impregnated catheter, they concluded that the use of the silver-

impregnated catheter was not statistically significant in the reduction of bacterial colonization or CRBSI.¹²

The focus of this study is chlorhexidine/silver sulfadiazine (CH-SS) central venous catheters. This study evaluated evidence from the literature in order to illustrate the effectiveness of chlorhexidine/silver sulfadiazine (CH-SS) central venous catheter in the prevention of bacterial colonization and CRBSI.

METHODS

Literature search

An extensive search was conducted in different databases such as CINHALL, Science Direct, EBSCO, and PubMed in order to extract the most updated randomized control studies (RCTs), meta-analysis and systematic reviews that discussed the effectiveness of the use silver impregnated central venous catheter (CVC) on catheter colonization and catheter related bloodstream infection (CABSI). Several studies including randomized control studies, meta-analysis and systematic review were selected for this paper. Those RCTs included a total number of 2,346 catheters. These studies were conducted in the USA, Europe, Australia and Brazil between 2004 to 2012.

DISCUSSION

Several randomized control trials (Table 1) have shown that the effect of silver-impregnated catheters vary in the rate of bacterial colonization and the rate of catheter related bloodstream infection. In RCT in Italy done by Antonelli M et al, the authors evaluated the efficiency of silver nanoparticles central catheters in terms of catheter colonization rate and intensive care units (ICU) mortality among 383 patients. 135 patients received silver nanoparticles central catheters (SC group) and 137 patients received conventional catheters (CC group). The authors concluded that there was no statistical significance difference in central venous catheter colonization rate between the two groups (32.6% vs. 30%, P=0.7) for SC and CC groups respectively. Furthermore, ICU mortality showed the same end result (46% vs. 43%, P=0.7) for SC and CC groups respectively.¹³

In a multicenter randomized double blinded trial, of Brun-Buisson C et al, the researchers compared the effect of newer chlorhexidine-silver sulfadiazine-coated (CH-SS) catheter (e.g. the second generation of silver-impregnated catheters) with the standard non-coated central venous catheter (CVC), among 363 catheters that were analysed, 175 received standard catheter and 188 received CH-SS catheter. The results revealed that catheter colonization rate happened in 13.1% and 3.7% in the standard group and CH-SS group respectively. In addition, the CRBSI occurred in eleven (6.3%) patients in the standard catheter group while four cases (2.10%) of

CRBSI were recorded in the CH-SS group. In conclusion, the use of CH-SS catheters were related with a decline of catheter colonization but not the bloodstream infection.¹⁴

According to a prospective RCT in 2005, Ostendorf T et al investigated the efficiency of CH-SS catheters among hematological oncological patients, 90 patients received CH-SS CVC and 94 received standard non-coated catheter. The catheters coated with CH-SS were effective in minimizing the rate of bacterial growth rate compared with standard catheter (26% vs. 49%) for CH-SS and

standard groups respectively. Additionally, the incidence of catheter colonization was statistically different between the two groups (12% vs. 33%, P=0.01) for CH-SS and standard un-coated group respectively. However, the number of bloodstream infection events was lower in patients who received CH-SS catheters than the patients who received the standard un-coated catheters (3% vs. 7% events). This difference was statistically significant (P=0.21). Consequently, the CH-SS catheters are useful in reducing the catheter colonization in immunocompromised patients.¹⁵

Table 1: Summary of previous randomized control studies.

Study	Aim /objectives	Design	Sample size	Outcomes
Antonelli et al ¹³	To evaluate the efficacy of silver- impregnated (SI) CVCs vs. conventional CVCs	Prospective RCT	272	Silver-impregnated CVCs are not effective in reducing catheter colonization (CC) or CRBSI
Brun-Buisson et al ¹⁴	To test the effectiveness of CH-SS CVCs vs. standard CVCs	Double-blind RCT	363	CH-SS CVCs are effective in reducing CC but not CRBSI
Ostendorf et al ¹⁵	To test the effectiveness of CH-SS CVCs vs. standard CVCs	Prospective double-blind RCT	184	The use of CH-SS CVCs reduces CC and catheter related infection
Moretti et al ¹⁶	To test the effectiveness of silver-platinum-and carbon black CVCs vs. Standard CVCs	RCT	539	No significant difference between the two groups in CC or CRBSI
Camargo et al ¹⁸	To test the effectiveness of CH-SS CVCs vs. standard CVCs	Prospective RCT	109	The use of CH-SS CVCs are not effective in reducing the incidence of CC
Kalfon et al ¹⁹	To test the effectiveness of SI CVCs vs. standard CVCs	Prospective RCT	617	The use of Silver-impregnated CVCs are not associated with lower rate of (CC)
Hagau et al ²⁰	To test the effectiveness of silver-integrated CVCs vs. standard	Prospective un-blinded RCT	272	Silver-integrated CVCs did not prevent catheter colonization (CC)

In a non-blinded RCT by Moretti EW et al, the authors examined the effectiveness of CVC impregnated with silver-platinum-carbon black (SPC) central venous catheters (VANTEX®) on the incidence of catheter colonization and CRBSI compared with standard CVCs. A large sample of 539 patients were distributed into two groups, 273 patients received SPC CVCs and 266 patients received standard CVCs. Unpredictably, the colonization rate was not statistically significant with overall colonization rate at 24.5%. Furthermore, only one episode of CRBSI was recorded. The authors explained that the rate of infection may depend on non-catheter related factors, for instance, site of insertion, the frequency of dressing change, and the adherence to infection control measures.¹⁶ While in another study by Fraenkel D et al the authors concluded that SPC catheters

have a low colonization rate, but are not effective as rifampicin-minocycline-coated (RM) catheters (14.6% vs. 8.9% P=0.39) for SPC catheters and RM catheters respectively. But fortunately, both types had low rates of CRBSI.¹⁷ In a prospective randomized study by Camargo L et al they evaluated the colonization rate for a group of patients who received either standard CVCs (n=58) or CH-SS impregnated CVCs (n=51) in the intensive care unit. They found no statistically significant difference between the two groups (29.4% vs. 34.5%, P=0.5) for CH-SS group and standard group respectively. In addition, 15.7% patients from the impregnated group had CRBSI, while 10% patients from the standard group had CRBSI, which also was not statistically significant (P=0.41).¹⁸

A larger sample size in comparison with the previous literature was used by Kalfon P et al to compare the effect of using silver-impregnated multi-lumen catheter and standard multi-lumen catheter on rate of colonization and CRBSI among critically ill patients, 617 catheters were inserted in 577 patients divided into 320 catheters in the silver-impregnated group and 297 catheters in the standard group. The colonization rate was registered as 14.7% in the silver group while in the standard group it was 12.1%. Hence, it was not a statistically significant difference with $P=0.35$. Additionally, the CRBSI receded (2.5% vs. 2.7, $P=0.88$) for silver and stander groups respectively. So the authors concluded that use of silver

impregnated catheter is not related to a lower rate of colonization and CRBSI in critically ill patients.¹⁹ Hagau N et al used 272 catheters distributed into two groups (silver integrated catheters and standard catheters) to investigate the colonization rate and infection rate in critically ill patients. The results revealed that there was no significant difference among both groups in terms of colonization and infection rates, which also consistent with the previous study.²⁰

The previously mentioned RCTs had several limitations that can be summarized in the following Table 2.

Table 2: Limitations of each control randomized trails.

Study	limitation
Antonelli et al ¹³	The possibility of biased decisions of physicians because they were aware of the catheter type used with each patient
Brun-Buisson et al ¹⁴	- Low baseline infection rate - Planned cauterization with low risk infection population
Ostendorf et al ¹⁵	No limitation mentioned
Moretti et al ¹⁶	No limitation mentioned
Camargo et al ¹⁸	-The study was performed in single hospital and had a small sample size - Only the external surface of the catheter was evaluated for colonization
Kalfon et al ¹⁹	The study was only blinded for the microbiologist and the expert team who performed the judgment of CRBSI.
Hagau et al ²⁰	-Unblended randomized control study -Single study setting

Despite the clinical effectiveness of silver-impregnated central venous catheters across the literature, some randomized trials suggest that the role of silver-impregnated CVCs in reducing the catheter colonization and catheter-related bloodstream infection is limited and considered as a controversial issue in clinical practice, especially, with the new development of different types of CVCs and the diversity of manufacturing materials that are being used as additives to improve the CVCs' effectiveness.

Silver-impregnated CVCs had been also compared with other types of catheters such as heparin-coated catheter and 5-flurouracial catheter.^{21,22} In support, in a RCT by Carrasco M et al to test the incidence of catheter colonization and CRBSI between two groups who received either heparin-coated catheter or CH-SS catheter, the authors concluded that CH-SS catheter is an effective tool in reducing catheter colonization, but the study was underpowered to judge the significant difference in term of CRBSI.²¹ While in a more recent study by Walz JM et al, the researchers suggest that catheters coated externally with 5-flurouracial may be considered a more safe and effective catheter than catheter coated with CH-SS.²²

CONCLUSION

Catheter related blood stream infection (CRBSI) is considered a serious complication for the use of central venous catheters, therefore, the trend of health care providers is to minimize this complication through the application of certain measures such as follows internationally recognized guidelines and recommendations that aim to reduce these infections. On the other hand, the technological development of central venous catheter manufacture play a great role in producing CVCs that are safe for patients and effective against bacteria and other types of germs. Despite the additives that are being used in central line manufacturing that aim to reduce catheter colonization and CRBSI, some discrepancy still presents in the clinical practice about which type of CVC is superior in reducing catheter colonization and therefore CRBSI. This discrepancy clearly appeared in the previous literature discussed. New randomized studies are needed to solve this inconsistency in the decision of which antimicrobial central line is preferred. Also it is very important to assure that one of the major factors in controlling of catheter colonization and CRBSI is the health care personnel by applying infection control measures and other recommended

measures to reduce catheter colonization and catheter related bloodstream infection.

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