Prevention of catheter-related blood stream infection

Matthew C. Byrnes and Craig M. Coopersmith

Purpose of review

Catheter-related blood stream infections are a morbid complication of central venous catheters. This review will highlight a comprehensive approach demonstrated to prevent catheter-related blood stream infections.

Recent findings

Elements of prevention important to inserting a central venous catheter include proper hand hygiene, use of full barrier precautions, appropriate skin preparation with 2% chlorhexidine, and using the subclavian vein as the preferred anatomic site. Rigorous attention needs to be given to dressing care, and there should be daily assessment of the need for central venous catheters, with prompt removal as soon as is practicable. Healthcare workers should be educated routinely on methods to prevent catheter-related blood stream infections. If rates remain higher than benchmark levels despite proper bedside practice, antiseptic or antibiotic-impregnated catheters can also prevent infections effectively. A recent program utilizing these practices in 103 ICUs in Michigan resulted in a 66% decrease in infection rates.

Summary

There is increasing recognition that a comprehensive strategy to prevent catheter-related blood stream infections can prevent most infections, if not all. This suggests that thousands of infections can potentially be averted if the simple practices outlined herein are followed.

Keywords

bacteremia, catheter-related blood stream infection, central venous catheter, intensive care unit, sepsis

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Department of Surgery, Washington University School of Medicine, St. Louis, Missouri, USA

Correspondence to Craig M. Coopersmith, MD, Washington University School of Medicine, 660 South Euclid Avenue, Campus Box 8109, St. Louis, MO 63110, USA
Tel: +1 314 362 9342; fax: +314 362 1602; e-mail: coopersmithc@wustl.edu

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Abbreviations

CDC	Centers for Disease Control and Prevention
CR-BSI	catheter-related blood stream infection
CVC	central venous catheter

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Introduction

Central venous catheters (CVCs) play an integral role in the management of critically ill patients. CVCs can be used to measure central venous pressure, to administer vasoactive medications that cannot safely be given peripherally, and to deliver parenteral nutrition. Balanced against these benefits are the potential morbidity and mortality associated with catheter-related blood stream infections (CR-BSIs). There is increasing recognition that CR-BSI is a partially, if not entirely, preventable complication if evidence-based infection control practices are followed [1,2••]. Despite the fact that CVCs are used more commonly in surgical patients than medical patients [3], the practices to prevent CR-BSI are similar in all ICUs and this review is therefore applicable to all critically ill patients.

Epidemiology

It has been estimated that there are 15 million CVC days in ICUs in the United States, resulting in 80 000 CR-BSIs annually [4,5]. The costs of CR-BSI can be measured in terms of healthcare expenditure, increased length of stay, and mortality. The exact cost of a CR-BSI is difficult to quantify. Recent studies have demonstrated a cost of US$11 971 per episode of CR-BSI [6••], although estimates have ranged as high as $56 167, depending on the patient population studied [7]. CR-BSIs also increase ICU length of stay an average of 2.41 days and increase total hospital length of stay by 7.54 days on average [6••]. The attributable mortality of CR-BSI is controversial. Unadjusted mortality rates range from 16 to 25% [8,9]. Studies examining adjusted mortality, however, estimate a range from zero up to 17% [10–12].

Individual components of catheter-related blood stream infection reduction efforts

Efforts to decrease CR-BSI begin prior to placement of a CVC and continue daily while a CVC remains indwelling in a patient. Furthermore, comprehensive education programs and continuous surveillance of all patients with CVCs in place play crucial roles in preventing CR-BSIs.

Hand hygiene

The first step in preventing CR-BSIs is perhaps the simplest and the most often forgotten. Despite repeated admonitions in the literature, from hospital administrators and from the lay press, the bottom line remains that healthcare workers repeatedly fail in the simple task of utilizing appropriate hand hygiene. Even more troublesome, physicians have repeatedly been documented to be the worst offenders, with lower levels of handwashing

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compliance than other healthcare workers. Studies have shown that physicians utilize appropriate hand washing approximately one-third of the time. Additionally, there has been basically no improvement in handwashing compliance over the last quarter century [13,14••]. Alcohol foam is an attractive, easy-to-use alternative that improves hand hygiene compliance in physicians to 56% [15], although it should be noted that alcohol foam does not kill *Clostridium difficile* spores. There is little question that lack of hand hygiene can disseminate resistant bacteria [16•]. We believe that personal responsibility for appropriate cleansing of hands prior to placing a CVC lies with the healthcare worker inserting the catheter, and that lapses should be no more tolerated than a surgeon not performing an adequate scrub prior to entering the operating room.

Skin antisepsis

The pathogenesis of CR-BSI may relate to catheter contamination at the time of insertion. As such, thorough skin antisepsis is crucial to preventing infections. Two percent chlorhexidine is the preferred method of skin antisepsis prior to CVC insertion. This is based upon a study of 668 patients who received a skin preparation of 2% chlorhexidine, 10% povidone-iodine, or 70% alcohol [17]. The lowest incidence of CR-BSI was seen in the chlorhexidine group (2.3% versus 7.1% versus 9.3%, respectively). A meta-analysis of eight randomized trials comparing chlorhexidine to povidone-iodine confirmed this result, with CR-BSI rates cut in half with the appropriate preparation [18]. The concentration of chlorhexidine is important, in that a study comparing 0.5% chlorhexidine with 10% povidone-iodine as skin antisepsis prior to CVC insertion showed no difference in CR-BSI rates [19]. Whereas there is a small increased expense using 2% chlorhexidine, this intervention has been demonstrated to be highly cost-effective, as the dollars saved by preventing infections dwarfs the initial expenditure [20]. Of note, skin should be scrubbed thoroughly with chlorhexidine for 30 s prior to CVC insertion, and the agent should be allowed to dry prior to attempting venipuncture.

Full barrier precautions

When placing a CVC, the ICU needs to be treated as if it is an operating room. This is based upon a study of 343 patients comparing the effects of full barrier precautions (mask, hair cap, sterile gloves, gown, and a full-sized sterile drape) to minimal barrier precautions (sterile gloves and a small drape) [21]. In this study of ambulatory oncology patients, the control group developed CR-BSIs more than six times as frequently as those in which the person inserting a CVC used full barrier precautions. Although the patient population of this landmark study is different than critically ill patients, the principles of CVC insertion are the same. Additionally, a study comparing full barrier precautions with less stringent barrier precautions demonstrated a two-fold decrease in CR-BSI in critically ill patients undergoing pulmonary artery catheterization [22]. Similar to preparation with 2% chlorhexidine, the use of full barrier precautions has been demonstrated to be cost-effective, with the long-term financial savings from decreased morbidity and mortality outweighing the small incremental costs associated with purchasing barrier supplies [23].

Insertion site

With rare exception, the optimal location to place a CVC is the subclavian vein. Although there are no prospective, randomized studies designed to evaluate the optimal location of CVC insertion, the majority of retrospective and nonrandomized prospective analyses (although not all) have demonstrated increased infectious complications associated with either the internal jugular or femoral approaches [24,25•,26,27]. Although results vary among studies, there appears to be a two to three-fold increase in CR-BSI risk when either the internal jugular or femoral approach is used. Additionally, there is an increased risk in development of thrombotic complications with indwelling femoral vein catheters [28], and as such, these should not be utilized except in emergencies or in rare patients in whom vascular access above the diaphragm is not anatomically possible. In keeping with the grade 1A recommendation by the US Centers for Disease Control and Prevention (CDC) [5], it is our practice to place CVCs in the subclavian vein unless there is a clear reason to choose another site, such as severe coagulopathy or renal failure. It should be noted that there are increased risks of mechanical complications such as pneumothorax using the subclavian approach, and the infection control benefits need to be compared with risks of other complications if the person inserting the CVC is inexperienced using this route.

Antiseptic or antibiotic-impregnated catheters

Antiseptic or antibiotic-impregnated CVCs represent the most studied, as well as controversial, component of efforts aimed at reducing CR-BSI. There are currently three types of impregnated CVCs. Antiseptic-impregnated CVCs are coated with chlorhexidine/silver sulfadiazine. A meta-analysis of 11 studies including 2603 CVCs comparing patients randomized to receive chlorhexidine/silver sulfadiazine or standard CVCs demonstrated an odds ratio of 0.56 favoring the antiseptic-impregnated catheters [29]. It should be noted that although the data in aggregate demonstrated a reduction in CR-BSI, only one of the included studies was sufficiently powered to demonstrate this endpoint on its own.

The most common type of antibiotic-impregnated catheters are minocycline/rifampin CVCs. In theory, these catheters may be more efficacious because they

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provide continuous antimicrobial activity for 14 days, and they also have stronger antimicrobial activity. A single prospective randomized trial comparing minocycline/rifampin impregnated CVCs with chlorhexidine/silver sulfadiazine impregnated CVCs demonstrated both a marked reduction in CR-BSI (0.3% versus 3.4%), and catheter colonization (22.8% versus 7.9%) with the minocycline/rifampin CVCs [30]. This study used, however, an older-generation chlorhexidine/silver sulfadiazine CVC. Second-generation catheters have been developed subsequently, which have an internal and external coating of chlorhexidine/silver sulfadiazine that may be more efficacious than older technology [31,32].

The most recently developed impregnated CVC is coated with silver/platinum/carbon, providing a continuous release of silver ions, which have bactericidal properties [33]. Studies evaluating CR-BSI and CVC colonization with this catheter have been neutral to favorable compared with standard CVCs [34–36]. A recent comparison between minocycline/rifampin and silver/platinum/carbon impregnated CVCs demonstrated similar low levels of CR-BSI between the catheters, although the study was underpowered to detect this endpoint [37••]. As a potential surrogate endpoint, however, the minocycline/rifampin catheter was associated with less colonization than the silver/platinum/carbon catheter (8.9% versus 14.6%).

In total, there have been more than 20 randomized, prospective trials evaluating the effect of antiseptic or antibiotic-impregnated CVCs [38]. The majority of these studies demonstrate a benefit as measured by decreasing CR-BSI rates or catheter colonization. In contrast, none of these studies have demonstrated harm associated with antiseptic or antibiotic-impregnated catheters, and early concerns about increasing antibiotic resistance in the setting of these catheters has never been demonstrated. Additionally, even the older-generation chlorhexidine/silver sulfadiazine CVCs have been shown to be cost-effective [29]. Although criticism of these catheters still exists [39], we believe that the preponderance of the evidence favors using antiseptic or antibiotic-impregnated CVCs in the appropriate clinical situations.

What can be challenging is determining exactly when to use these catheters. The CDC recommends using antiseptic or antibiotic impregnated CVCs in patients whose catheter is expected to remain in place greater than 5 days; when the institution has a comprehensive strategy to prevent CR-BSI including full barrier precautions, 2% chlorhexidine skin preparation and education programs towards those who insert and maintain CVCs; and, despite the comprehensive strategy, CR-BSI rates are above goals set by each 'individual institution based upon bench mark rates' [5]. As such, ICUs that do not have any CR-BSIs have no need to use antibiotic or antiseptic-impregnated CVCs, whereas those with CR-BSI rates above the averages in the National Nosocomial Infections Surveillance (NNIS) program of the CDC should insert these CVCs following the CDC guidelines. It is unclear, however, what the utility of these CVCs are in ICUs that have CR-BSI rates below the national average but greater than zero. Because it has been shown that CR-BSIs can be eliminated in the ICU setting [1], we recently studied the effect of using chlorhexidine/silver sulfadiazine CVCs in our surgical ICU, where CR-BSI rates were below the national average. Over 35 months and 14 692 catheter-days, we decreased our CR-BSI rate from 3.3/1000 catheter-days to 2.1/1000 catheter-days [40]. Our decrease in infection rates, however, was not statistically significant so it is difficult to recommend using antiseptic-impregnated catheters in this setting.

Dressing care

A randomized trial of pulmonary artery catheters that had gauze dressing changes every other day compared with transparent dressings changed every 5 days showed no differences in CR-BSIs [41]. Therefore, CVCs can be dressed with either sterile gauze or transparent semi-permeable polyurethane dressings as a matter of institutional preference. If bleeding occurs at the site, gauze dressings are preferred. Additionally, grossly soiled dressings should be changed as soon as contamination is identified visually. Sustained-release chlorhexidine dressings have been proposed to decrease CVC-associated infections. A recent meta-analysis demonstrated a decrease in exit site colonization in patients receiving these dressings (14.8% versus 26.9%) without a change in CR-BSI rate [42•]. We do not believe that definitive recommendations can be made regarding the use of these dressings. Of note, antibiotic ointment should not be used at the dressing site, as this may increase the risk of cutaneous fungal infection [5].

Early removal

The risk of CR-BSI goes up the longer a CVC stays in place. Therefore, the necessity of a CVC should be assessed daily and catheters should be removed as soon as possible. We advocate specifically addressing a patient's need for a CVC on rounds each morning in the ICU. Despite the increasing risk of CR-BSI based upon catheter age, CVCs should not be replaced based upon the length of time they have been in place, as studies examining routine replacement every 3–7 days have not decreased infection rates [43,44]. Further, guidewire exchange is associated with increased infectious risk and should not be performed under routine circumstances [45].

Miscellaneous prevention strategies

Administration sets should be changed no more frequently than every 96 h, although those containing blood products or lipids should be changed daily [46]. Needleless, open, and closed hub systems have not been demonstrated to

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change CR-BSI rates [47••]. There is no role for prophylactic antibiotics in preventing CR-BSI.

Surveillance

There is increasing demand by regulatory commissions and the populace for public reporting of infection rates. These monthly surveillance data can demonstrate how individual ICUs compare with national and statewide averages of similar ICUs, and can be a catalyst for change. For instance, a broad-based study comparing hospitals that followed their nosocomial infection rates with those that did not demonstrated a 32% decrease in the former versus an 18% increase in the latter [48].

Education

Education of healthcare staff is a cornerstone of efforts to decrease CR-BSI. Educational programs highlighting best practice aimed at physicians, nurses, or the entire healthcare team have been shown to decrease CR-BSI rates markedly after their implementation in single-center studies [49–52]. Because of staff turnover and to assure continued attention to the threat of CR-BSI, we recommend the program be repeated at regular intervals.

Comprehensive prevention programs

Implementation of a multistep prevention program has been shown to basically eliminate CR-BSI in the SICU. A recent study by Berenholtz *et al.* [1] demonstrated that a comprehensive program decreased the CR-BSI rate to 0.54/1000 catheter-days over the course of 16 months, with no infections reported for 9 months. The elements of their program included an educational program; the presence of a CVC insertion cart; asking providers daily whether a CVC was needed; a daily checklist performed by the bedside nurse; and empowering nurses to stop CVC insertion if guidelines were not followed properly. The use of Six-Sigma methodology to evaluate reasons for elevated CR-BSI rates has also led to successful development of comprehensive programs to decrease infection rates [53].

Recently, a comprehensive program was instituted successfully on a much broader scale [2••]. One hundred and three ICUs in Michigan participated in a multistage quality improvement project utilizing comprehensive interventions that targeted hand washing; full barrier precautions; the use of 2% chlorhexidine for skin preparation; avoiding femoral CVCs; and removing unnecessary catheters. The monthly mean number of CR-BSIs decreased from 2.7 to zero infections 3 months after the intervention. Importantly, this program decreased CR-BSI rates from 7.7/1000 catheter-days before intervention to 1.4/1000 catheter-days 16–18 months after intervention.

Conclusion

CR-BSIs are costly, morbid and potentially lethal infections. They are also largely preventable. The person inserting a CVC should use appropriate hand hygiene, full barrier precautions, skin preparation with 2% chlorhexidine, and place the CVC in the subclavian vein if possible. The nurse caring for the CVC plays an equally important role in preventing infection. If rates are not decreased despite close attention to evidence-based best practices, antiseptic or antibiotic-impregnated catheters are effective in decreasing CR-BSIs. These best practice tenets need to be taught and reinforced to healthcare workers who place and insert CVCs. Together, these interventions will decrease – and possibly eliminate – CR-BSIs in the ICU.

References and recommended reading

Papers of particular interest, published within the annual period of review, have been highlighted as:

- • of special interest
- •• of outstanding interest

Additional references related to this topic can also be found in the Current World Literature section in this issue (p. 469).

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