Techniques to Prevent Central Venous Catheter Infections: Products, Research, and Recommendations

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ABSTRACT: Central venous catheters (CVCs) are commonly used to deliver a variety of therapies such as chemotherapy and parenteral nutrition. It is well known that there are complications associated with CVCs; a major complication is catheter-related bloodstream infection (CRBSI). Many strategies exist to prevent CVC complications and CRBSI. This paper will focus on the fight against CRBSI using 3 products at the catheter insertion site: 2% chlorhexidine, BioPatch, and transparent split dressings. Lists of key recommendations from national organizations for infection prevention are included.

Catheter-Related Bloodstream Infection (CRBSI): Overview of the Problem

Central venous catheters (CVCs) are widely used to deliver many types of infusions to patients with a variety of illnesses. These catheters are not without risk, and some CVCs carry more risk than others. CRBSIs are one of the most common complications of CVCs. Crnich and Maki[1] looked at 206 published prospective studies in which every type of IV catheter was evaluated for infection. The pooled mean rate of bloodstream infection (BSI) of a peripherally inserted central catheter (PICC), for example, was 0.4 per 1000 catheter-days, whereas a short-term nonmedicated CVC was 2.3 per 1000 catheter-days.

Some of the factors that influence the rate of infection include the location of the exit site, patient setting (eg, intensive care unit [ICU], hospital, or home), type of infusion, and condition of the patient. The prevalence of infection as it relates to the exit site is influenced by the density of skin flora, skin moisture, and body temperature in that area. For example, CVCs inserted into the internal jugular or femoral veins carry more risk of infection than do CVCs inserted into a subclavian or arm vein.[2] Patient setting is a second risk factor for CRBSIs. The Centers for Disease Control and Prevention (CDC) Guidelines for the Prevention of Intravascular Catheter-Related Infections, in their background material, state "In the ICU setting, the incidence of infection is often higher than in the less acute inpatient or ambulatory setting. In the ICU, central venous access might be needed for extended periods of time; patients can be colonized with hospital-acquired organisms; and the catheter can be manipulated multiple times per day for the administration of fluids, drugs, and blood products. Further, some catheters can be inserted in urgent situations, during which optimal attention to aseptic technique might not be feasible."[3] Another factor influencing prevalence of CRBSIs is the type of infusion. For example, parenteral nutrition (PN), due to the components, is a good growth medium for microbes. Blood products are another type of infusion that can promote infection. Researchers from MD Anderson Cancer Center evaluated infection in cancer patients receiving blood and platelet transfusions; they determined that blood products could predispose patients to CRBSI through several mechanisms.[4] Platelet transfusions may cause adherence of organisms to catheter surfaces, and multiple donor platelet infusions may be contaminated with skin organisms. In addition, blood products serve as a good growth media for the multiplication of microorganisms.[4] The patient type and severity of illness may also predispose them to CRBSIs. For example, individuals with diabetes mellitus, who are immunocompromised, or have severe burns are considered to be at increased risk for infections, including catheter infections.[3]

The CDC guidelines for the Prevention of Intravascular Catheter-Related Infections also states that an estimated 250,000 cases of CVC associated BSIs occur in the United States annually.[3] Mortality is an estimated 12%–25% for each infection, with an attributable cost of an estimated $25,000 per episode. The document explains that this cost is substantial and that implementing multiple evidence-

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based strategies to reduce BSIs must be done to reduce incidence and cost of infections.

The CDC guidelines also define the different types of CVC infections as exit site, tunnel, pocket, infusate-related, and CRBSIs.[3] For example, a CRBSI is defined as "bacteremia/fungemia in a patient with an intravascular catheter with at least 1 positive blood culture obtained from a peripheral vein, clinical manifestations of infection, and no apparent source for the BSI except the catheter."[3] Exit site infection is defined as "erythema or induration within 2 cm of the catheter exit site, in the absence of concomitant BSI and without concomitant purulence." Also described are the National Nosocomial Infection Surveillance System (NNIS) reporting definitions.[3]

Prevention of CRBSI

Because CRBSIs are due to multiple factors, there is no simple strategy to prevent infection. Crnich and Maki[1] thoroughly reviewed the different infection prevention strategies with short-term and long-term catheters, including evidence related to topical ointments, dressing types, cuffs, anti-infective catheter surfaces, anti-infective hubs and connectors, antibiotic lock solutions, and securing devices. The authors stated that the main route of infection with short-term catheters is *via* the exit site; with long-term catheters, the primary source of infection is intraluminal. The authors concluded that proven technology to prevent CRBSIs should be widely used, and future research should focus on our understanding of the biologic forces that cause colonization so technology designs focus on products that prevent microorganisms from gaining entry.[2]

Exit Site as a Source of CRBSI

Microbes may gain access to the bloodstream *via* the catheter exit site. To clarify, for many catheters, the entrance site is the same as the exit site. Microbes that are present on the skin gain entry *via* the exit site, move along the cutaneous catheter tract, probably facilitated by capillary action, and colonize the exterior portion of the catheter or catheter tip.[1] These microbes may then enter the bloodstream, causing a CRBSI. Methods to prevent microbes from existing at the catheter exit site would prevent this problem.

A 3-step protocol using chlorhexidine, BioPatch (Johnson & Johnson Wound Management, Ethicon Products, Somerville, NJ), and a split transparent dressing prevents microbes from existing at the catheter exit site, thus preventing microbial entry. Two percent tincture of chlorhexidine removes microbes from the skin, BioPatch prevents regrowth of microbes after skin antisepsis, and a split transparent film dressing keeps the BioPatch in direct contact with the skin. BioPatch surrounds the exit site. (Figure 1 illustrates a PICC dressing.) This strategy cannot, however, prevent infection from another source of CRBSI, which is the catheter hub.

Figure 1. A patient has a peripherally inserted central catheter (PICC) secured with secured with sterile adhesive strips called Hubguards (Tri-State, Howell, MI). The BioPatch is visible and the site covered with Tegaderm #1655 (3M, St. Paul, MN).

2% Chlorhexidine Skin Antisepsis

The CDC guidelines state that a 2% chlorhexidine-based preparation is preferred for skin antisepsis.[3] Germicidal activity should be persistent for at least 48 hours with chlorhexidine. A meta-analysis of 8 studies with hospital patients and a variety of catheters showed a 49% reduction of CRBSI using chlorhexidine gluconate (CHG) compared with povidone-iodine solution.[5] According to the manufacturer, CHG prevents regrowth of skin microorganisms for up to 48 hours.

At the UW hospital, a 2% tincture of chlorhexidine solution is applied with a 3-mL foam applicator on a stick handle. The applicator is used with a back-and-forth friction scrub for 1 minute over a 4-in. × 5-in. area (Figure 2). For CVC insertion, one can use 2 applications of the 3-mL applicator or 1 application using a 10-mL applicator (the 10-mL applicator covers an 8.4-in. × 8.4-in. area). A color tint, in the larger applicators, may be helpful for some procedures so the staff can see exactly where the prepped area is.

BioPatch

BioPatch is a foam disk impregnated with CHG. It comes in different sizes: 2 disks are 1 inch in diameter and the third one is 0.75 inch in diameter. The amount of CHG in the disk varies from 52 mg to 92 mg, depending on the size of the disk. The center hole also comes in 3 sizes, from 1.5 mm to 7.0 mm to accommodate a variety of catheter diameters. For example, a thin arterial or epidural catheter requires the use of a small patch, whereas a large-diameter dialysis catheter requires the larger BioPatch. Correct placement of BioPatch is illustrated

Figure 2. The exit site of a catheter and surrounding area is being cleaned with a 2% chlorhexidine solution (Medi-Flex, Overland Park, KS). This 3-mL applicator treats an area approximately 4 in. by 5 in.

in Figure 3; incorrect placement is featured in Figure 4. The main features of BioPatch include:

- It has a 7-day release of CHG on the skin to prevent the regrowth of microbes.
- It is absorbent so it can be placed on the catheter insertion site immediately after the line is placed. Drainage from the exit site or skin is visible through the BioPatch so one could see if it needs changing sooner than the due date. Some newly inserted CVCs ooze blood more than others. For example, a 4-Fr PICC line might not ooze at all after insertion, but a newly placed dialysis catheter usually will.
- It is nontoxic and nonirritating, although the CDC guidelines recommend, as a category II recommendation, not to use it on neonates aged <7 days or gestational age <26 weeks.[3]

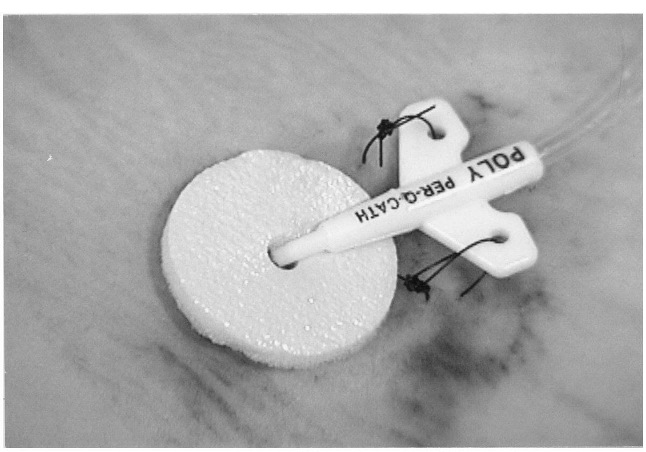

Figure 3. This photograph illustrates correct placement of the BioPatch around the catheter insertion site, with the **blue side up** and **white foam side down** on skin. BioPatch edges need to meet to ensure there is complete skin contact.

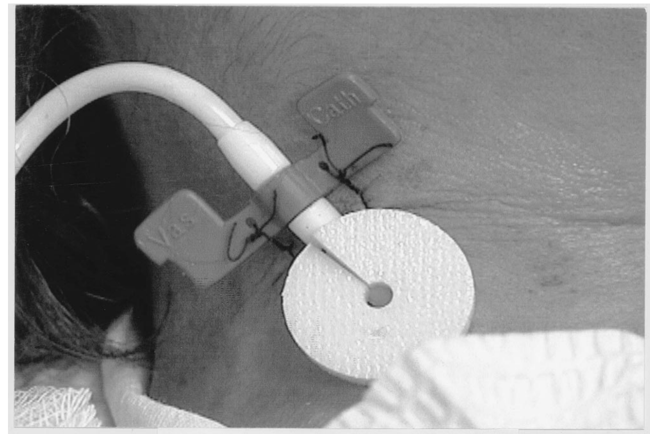

Figure 4. This photograph illustrates the incorrect way to place BioPatch. Chlorhexidine embedded in the foam is activated only on contact with the skin. Simply laying it on top of the catheter (as in this photo) is not effective. The other incorrect way is to put the blue-tinted film side on the skin. If the blue film side is on the skin, the chlorhexidine is not activated.

- Many dressings can be left on the patient longer than the common standard in hospitals, which is 3 days. The UW Hospital standard for duration of a dressing before the use of BioPatch was 3 days; when using BioPatch, it is now 6 days. There should also be an "as-needed" policy to change any dressing when or if it becomes wet, bloody, or loose. Although the addition of a BioPatch increases the cost of standard dressing kits, cost savings may be achieved through a reduction of the number of dressing kits used per patient.
- At UW Hospital, BioPatch is used on the following catheters: PICCs, midline catheters, nontunneled triple-lumen CVCs, pulmonary artery catheters, acute and chronic dialysis catheters (Figure 5), arterial catheters (Figure 6), and epidural catheters. Optional usage occurs with

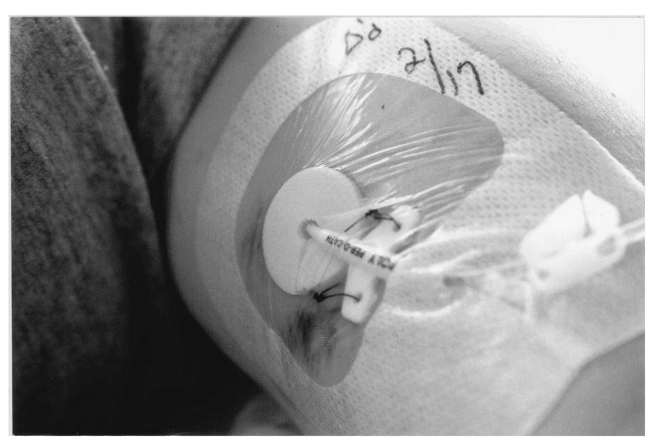

Figure 5. This photograph shows a properly applied BioPatch dressing on a dialysis catheter insertion site.

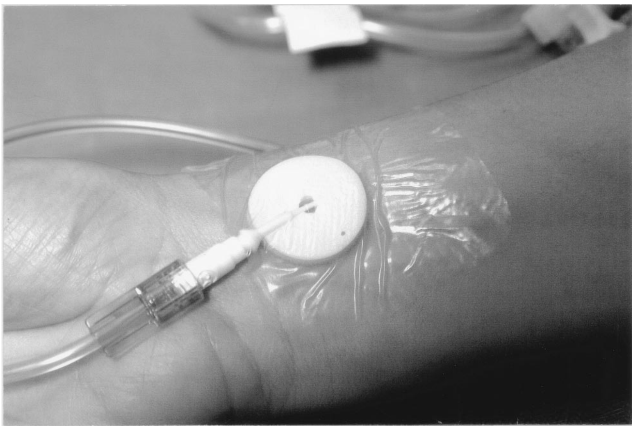

Figure 6. This photograph shows a properly applied BioPatch dressing on an arterial catheter insertion site.

newly tunneled catheters until the stitches are removed (3–4 weeks) and implanted venous ports, if the needle is left in for a week at a time.

This protocol was based on the results of a prospective, randomized study conducted by Maki et al[6] and members of the UW Hospital Infection Control Department to determine infection rates in patients with IV catheters. They studied 413 hospitalized patients who had either a PICC line, arterial catheter, or nontunneled triple-lumen CVC. DNA subtyping was done to verify the relationship between the microbes in the peripheral blood and that from the catheter. Two hundred eleven patients had the BioPatch covered by a transparent film dressing, and 208 had the same dressing without the BioPatch. Fifteen patients had CRBSI in the control group and only 6 in the Biopatch dressing group. The rate reduction was significant (1.2% *vs* 3.3%, relative risk [RR] 0.36, $p < .01$ per 100 catheter-days; and 3.3% *vs* 5.7%, RR 0.41, $p < .01$ per 1000 catheter-days). When Maki et al[6] combined their results with another center, using the same patient group and line types, they again found fewer CRBSIs in the BioPatch group compared with infection rates in a control group. They evaluated a total of 736 catheters without BioPatch and 665 catheters with BioPatch. The Biopatch dressing group had only 8 CRBSIs (1.2%), whereas the control group had 24 CRBSIs (3.3%). The results were significant using proportional hazards regression analysis (RR 0.38, confidence interval [CI] 0.16–0.89, $p = .01$).[6]

Crawford et al[7] evaluated the net financial and patient benefits of using BioPatch according to data from the Maki and Mermel study.[6] They performed a "cost-benefit analysis using randomized, controlled trial data on chlorhexidine dressing prevention of local infection and CRBSI, data on cost of chlorhexidine dressing *vs* standard treatment, data on averted cost of treating local infection and CRBSI, and data on mortality attributable to CRBSI." They concluded the BioPatch dressings would reduce costs, infections, and deaths. Using the moderate estimate of $25,000 to treat a CRBSI, the national net benefit from widespread use would be an estimated $275 million to $1.97 billion and a decrease in deaths of between 329 and 3906 annually.[7]

Figure 7. This photograph illustrates a sutured dressing for a peripherally inserted central catheter (PICC). Tegaderm split edges are overlapped under the catheter tail for added securement. Sutures are far enough away to allow room for a BioPatch. A BioPatch can routinely be placed at a new catheter insertion site.

Transparent Semipermeable Split Dressing

A transparent semipermeable split dressing is designed to help secure catheters; it is especially useful with bulky catheters in hard-to-tape areas. The catheter site is cleaned as described above with chlorhexidine, and then the BioPatch is placed around the catheter and the patch is held securely in contact with skin with the clear portion of the transparent semipermeable split dressing. The split tabs of the transparent dressing are overlapped under the tail of the catheter to prevent lifting of the dressing. The soft border prevents edge pulling and irritation. Two soft tape strips are available to help secure the dressing. The site is clearly visible because the dressing is transparent and the date can be easily written on the dressing to note the date the dressing was completed (Figure 7). Examples of split dressings available include Tegaderm (3M, St. Paul, MN) and SorbaView Window Dressing (Tri-State, Howell, MI).

Inspection of the CVC Insertion Site

As stated previously, the BioPatch allows for site inspection through a transparent film dressing (Figure 8). If there is drainage, one can see it in the foam disk. If the BioPatch becomes very moist, it will increase in size. However, it has been proven that inflammation at the site is not a reliable way to predict if the patient will have a CRBSI. Safdar and Maki[8] studied ICU patients with noncuffed CVCs. Catheter sites were inspected and CRBSI events

Figure 8. Drainage visible through dressing.

monitored. After looking at 1263 CVCs, they concluded, "Local inflammation is uncommon with infected CVCs. . . . In general, site appearance cannot be relied upon to identify catheter colonization or CVC-related BSI."[8]

Infection Prevention for Short-Term CVCs Used for Parenteral Nutrition (PN)

Short-term, nontunneled CVCs are often used for short-term PN administration. PICC lines, another type of CVC, are also appropriate for PN administration. BioPatch should be used at the exit site of both of these catheters because the risk of infection with these CVCs is mainly related to the insertion site. Dedicating 1 lumen of a multilumen catheter to PN is another common practice to reduce infection by limiting the number of times that the PN infusion lumen is manipulated.

The A.S.P.E.N. Guidelines support the recommendations of the CDC guidelines. Table 1 includes a partial list of infection prevention guidelines specific for PN access.[9,11] Table 2 includes a partial list of other infection-prevention recommendations from the CDC guidelines that were consider category 1A recommendations; 1A recommendations are "strongly recommended for implementation and supported by well-designed experimental, clinical, or epidemiologic studies."[3]

Table 1
A.S.P.E.N. guidelines for parenteral access: infection-prevention strategies[9,11]

Full-barrier precautions should be used during the insertion of central lines.
Catheter hubs and sampling ports should be disinfected before access for medication administration and blood drawing.
Central catheters should not be exchanged routinely over guidewires.
Specialized nursing teams should care for venous access devices in patients receiving parenteral nutrition.
The use of antimicrobial-impregnated catheters is recommended in high-risk patients and high-risk care settings.

Table 2
*CDC guidelines for the prevention of intravascular catheter-related infections**[3]

Educate healthcare workers in the proper use, insertion, and care and maintenance of CVCs and methods to prevent infection.
Assess knowledge and compliance of all persons who insert and manage CVCs.
Do not routinely culture catheter tips.
Observe proper hand hygiene.
Do not use organic solvents on skin during dressing changes.
Do not use topical ointments or creams on insertion sites (exception: dialysis catheters).
Promptly remove any catheter that is no longer essential for patient therapy.
Complete the infusion of TNA within 24 hours of hanging, change tubing every 72 hours.
Designate trained personnel for the insertion and maintenance of intravascular catheters.
Conduct surveillance in ICUs and other patient populations to determine CRBSI rates, monitor trends in those rates, and assist in identifying lapses in infection-control practices.
Designate personnel who have been trained and exhibit competency in the insertion of catheters to supervise others.
Replace the catheter-site dressing when it becomes damp, loosened, or soiled or when inspection of the site is necessary.
Replace gauze dressings every 2 days and transparent dressings every 7 days.

CRBSI, catheter-related bloodstream infection; CVC, central venous catheter; ICU, intensive care unit; TNA, total nutrient admixture.
*This is a partial list of infection prevention recommendations from the Centers for Disease Control and Prevention Guidelines for Prevention of Intravascular Catheter-related Infections; these are considered category 1A recommendations (those that are "strongly recommended for implementation and supported by well-designed experimental, clinical, or epidemiologic studies."[3])

Dressing Recommendations for Long-Term CVCs

Patients requiring long-term PN must also have long-term CVC access. These catheters include tunneled catheters or implanted ports. BioPatch has not been studied with these catheters. It is common practice with long-term tunneled and cuffed catheters to have the option of using no dressing at all after the line is well healed (3–4 weeks). The CDC guidelines place this as a category II recommendation ("suggested for implementation and supported by suggestive clinical or epidemiologic studies or a theoretical rationale"[3]). The guideline states "Tunneled CVC sites that are well healed might not require dressings."[3] UW Hospital outpatients may choose whether or not to wear a dressing on their tunneled CVCs after the catheter has been in place at least 1 month. If patients are admitted to the hospital, the site is covered regardless of whether it is a tunneled long-term catheter or not.

Hub Care for Long-Term CVCs

Patients requiring long-term PN should also focus on hub care as a method to prevent CRBSI. In addition to infection being introduced *via* exit sites of tunneled and cuffed catheters, the lumen of the catheter *via* the hub is also a source of infection. Infection *via* the hub is dependent upon the type of needleless cap system that is used, how the hub is cleaned before the catheter accessed, and how often the needleless cap is changed. By covering both the catheter exit site and hub while taking a shower, one can prevent exposure to tap water and organisms. This is also a category II recommendation in the CDC guidelines.[3]

Clinical Application

At our center, we have shown that the use of infection-prevention products such as the BioPatch reduces the rate of CRBSI.[10] Implementation of this protocol reduced CRBSI in both trial units. The Hematology, Oncology, Bone Marrow Transplant Unit had a median rate of 5.8 CRBSIs per 1000 patient-days before use of the BioPatch; after implementation of BioPatch, the rate dropped to 1.6. In the intensive care unit, the infection rate before the BioPatch era was 9.4 per 1000 central line–days; after BioPatch was introduced, the infection rate dropped to 4.1.[10] Since that time, there remains a continued reduction in CRBSI rates throughout the hospital.

Summary

CRBSIs are a significant complication of CVCs and other lines like arterial catheters. New technology to prevent colonization of the exit site is available. New reporting requirements may allow for an examination and improvement of practices and products. No single strategy works by itself, and indeed, multiple products and practices may be needed to reduce or eliminate CRBSIs.[12] Evidence-based practice will be helpful as new products and practices are implemented. The purpose of this paper was not to focus on specific research trials or to prove that the products presented work. That research has already been done. The purpose was to demonstrate how the products work together to prevent CRBSI and share some tips and techniques learned along the way.

Acknowledgments

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