

ORIGINAL ARTICLE

Disinfection of Needleless Catheter Connectors and Access Ports With Alcohol May Not Prevent Microbial Entry: The Promise of a Novel Antiseptic-Barrier Cap

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BACKGROUND. Needleless valve connectors for vascular catheters are widely used throughout the United States because they reduce the risk of biohazardous injuries from needlesticks and exposure to bloodborne pathogens, such as human immunodeficiency virus and hepatitis C virus. Patients with long-term central venous catheters are at significant risk of acquiring catheter-related bloodstream infections caused by microbes that gain access through the connection between the administration set and the catheter or an injection port. Most healthcare practitioners wipe the membranous septum of the needleless connector or the injection port with 70% alcohol before accessing it. We report a simulation study of the efficacy of conventional alcohol disinfection before access, compared with that of a novel antiseptic-barrier cap that, when threaded onto a needleless luer-activated valved connector, allows a chlorhexidine-impregnated sponge to come into continuous contact with the membranous surface; after removal of the cap, there is no need to disinfect the surface with alcohol before accessing it.

METHODS. One hundred five commercial, needleless luer-activated valved connectors, each accessible by a blunt male-connector luer-lock attachment, were purchased from 3 manufacturers and were tested. The membranous septum of each test device was first heavily contaminated with $\sim 10^5$ colony-forming units of *Enterococcus faecalis* and then was allowed to dry for 24 hours. Fifteen of the contaminated devices were not disinfected (positive controls), 30 were conventionally disinfected with a commercial 70% alcohol pledget, and 60 had the antiseptic cap threaded onto the connector and then removed after 10 minutes. The test connectors were then accessed with a sterile syringe containing nutrient broth media, which was injected, captured on the downstream side of the intraluminal fluid pathway, and cultured quantitatively.

RESULTS. All 15 control connectors (100%) showed massive transmission of microorganisms across the membranous septum (4,500–10,000 colony-forming units). Of the 30 connectors accessed after conventional disinfection with 70% alcohol, 20 (67%) showed transmission of microorganisms (442–25,000 colony-forming units). In contrast, of the 60 connectors cultured after application of the novel antiseptic cap, only 1 (1.6%) showed any transmission of microorganisms ($P < .001$).

CONCLUSIONS. The findings of this study show that, if the membranous septum of a needleless luer-activated connector is heavily contaminated, conventional disinfection with 70% alcohol does not reliably prevent entry of microorganisms. In contrast, the antiseptic-barrier cap provided a high level of protection, even in the presence of very heavy contamination. This novel technology deserves to be studied in a clinical trial.

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More than 500,000 intravascular device-related bloodstream infections (BSIs) occur in the United States each year, and the majority are associated with the use of central venous catheters (CVCs).¹ CVC-related BSIs are associated with substantial prolongation of hospital stay and marginal costs to healthcare systems of \$33,000–\$35,000 per episode.^{2–4}

For microorganisms to cause CVC-related infection, they must first gain access to the extraluminal or intraluminal surfaces of the device, where they can adhere and become incorporated into a biofilm^{5–7} that allows sustained surface colonization and, ultimately, hematogenous dissemination.

With short-term intravascular devices (eg, peripheral intravenous catheters, arterial catheters, and noncuffed and non-tunneled CVCs), most catheter-related BSIs are of cutaneous origin, from the insertion site, and gain access extraluminally and, occasionally, intraluminally.^{8–10} With long-term intravascular devices (eg, cuffed and tunneled CVCs, totally implanted central venous ports, and peripherally inserted CVCs), intraluminal contaminants have been shown to be major cause of nosocomial BSI.^{11–14}

Needleless valve connectors have come into nearly universal use in the United States as part of a national movement

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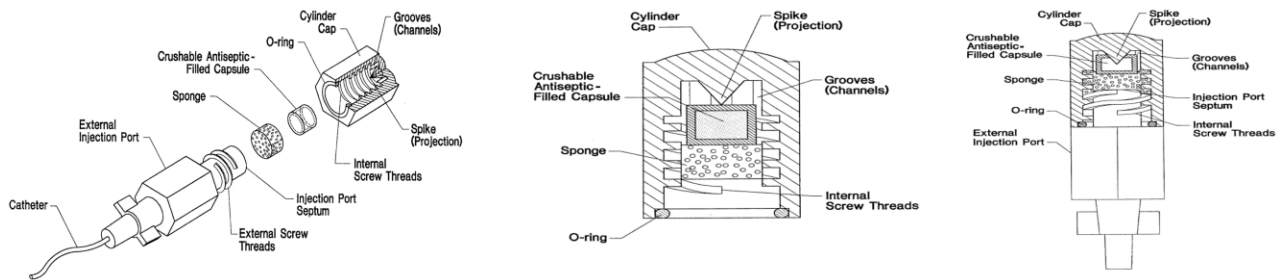


FIGURE 1. Schematic of the antiseptic-barrier cap studied, including the injection port and cover. It can be seen that when the cap is affixed to the membranous surface of the needleless connector or injection port, the spike ruptures the antiseptic-filled capsule, and the capsule sponge becomes saturated with chlorhexidine and maintains continuous contact with the entire membranous surface.

to reduce the risk to healthcare workers of biohazardous injuries from sharp instruments and devices and exposure to bloodborne viruses, such as human immunodeficiency virus, hepatitis B virus, and hepatitis C virus.¹⁵⁻¹⁷ A number of outbreaks have been associated with the use of needleless connectors, in both hospitals and home-care settings,¹⁸⁻²² in each report, contamination of a needleless valve connector was associated with a greatly increased risk of CVC-related BSI. Moreover, there is growing evidence of an ongoing, greatly increased incidence of nosocomial BSIs in many US hospitals deriving from the vulnerability to nosocomial contamination of the commercial needleless valve connectors that are now widely used for long-term intravascular devices.^{23,24}

Although needleless connectors and injection ports are recognized sites of access for microbial contamination, there is no national standard that defines the best and recommended form of antiseptic preparation for prevention of microbial entry when the needleless connector or injection port is accessed. Although previous simulation studies have examined the usefulness of various disinfectants for removing microorganisms from the membranous surface of a needleless connector or injection port,²⁵⁻²⁷ those studies did not examine the efficacy of different agents or regimens under the challenge of a very high level of contamination. There are, to our knowledge, no clinical trials that have prospectively examined the efficacy of various approaches to disinfection for the prevention of CVC-related BSIs, and the most recent Guideline of the Hospital Infection Control and Practice Advisory Committee of the Centers for Disease Control and Prevention has recommended that vascular catheter hubs, needleless connectors, and injection ports be disinfected before access as a category 1B recommendation,²⁸ but it does not advocate use of any specific agent. It is noteworthy that, in studies performed in Europe in settings where there was a very high baseline rate of CVC-associated BSI, novel approaches to preventing the contamination of CVC administration-set connections, such as the use of a povidone-iodine "shield"²⁹ or novel antiseptic-containing connectors,³⁰⁻³² have been shown to reduce the number of CVC-related BSIs.

In most medical centers in the United States, catheter hubs,

needleless connectors, and injection ports are disinfected by swabbing the membranous septum with 70% isopropyl alcohol; however, the limited data from prior studies and our data show that this technique may not reliably eliminate septal surface contamination.^{25-27,29-31} Frequent handling of and access through catheter hubs, needleless connectors, and injection ports put patients at increased risk of CVC-associated primary BSI.^{18,20,21,22,27}

We report a prospective simulation study of the effectiveness of conventional disinfection of needleless luer-activated valve connectors with 70% alcohol, compared with the effectiveness of a novel antiseptic-barrier cap that, when threaded onto a luer-activated connector, rapidly sterilizes a heavily contaminated surface.

METHODS

The Antiseptic-Barrier Cap

The antiseptic-barrier cap studied (Saralex, Menyhay Medical), consists of 3 parts: an outer cap with internal female threads and a spike inside the closed end, a capsule containing 0.25 mL of 2% chlorhexidine gluconate in 70% isopropyl alcohol, and a sponge (Figure 1). The cap has been designed so that, when it is threaded onto a luer-adaptable needleless connector or injection port, the spike ruptures the antiseptic capsule, saturating the sponge between the septum and the capsule. When the cap is tightened, the antiseptic-impregnated sponge is brought into continuous contact with membranous surface of the connector or port until the cap is removed (Figures 1 and 2). After removal of the cap, there is no need to disinfect the membranous surface before access. After removal of the male connector, the antiseptic cap can be reattached to the connector or port.

Design of the Simulation Study

Needless luer-activated valved connectors from 3 manufacturers (Clearlink [Baxter Healthcare], PosiFlow [Becton-Dickinson], and Micro CLAVE [ICU Medical]) were studied. All of the connectors have a membranous surface that is designed to be accessed by a blunt luer-lock male connector.

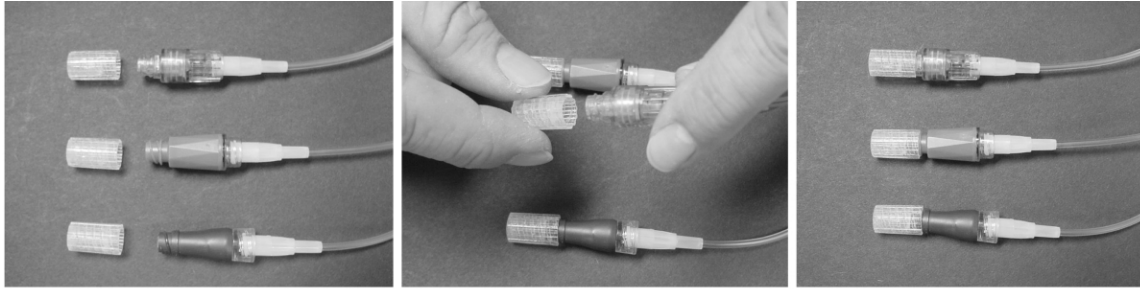


FIGURE 2. The antiseptic-barrier cap affixed to needleless valve connectors from 3 manufacturers

Thirty-six connectors from each manufacturer were tested concurrently in a simulation trial. One device of each type was used as a negative control (ie, they were accessed without precontamination). The remaining 35 devices from each manufacturer were contaminated by immersing the membranous surface in a suspension of *Enterococcus faecalis* containing $>10^8$ colony-forming units/mL, after which the septum was allowed to dry in a protected aseptic container for 24 hours (final inoculum on the septum, $\sim 10^5$ colony-forming units).

Negative Controls

One noncontaminated device taken directly from its protective package was tested similarly, without any disinfection. However, the membrane was entered 5 times consecutively before it was flushed with broth, which was then collected for culture.

Positive Controls

Five precontaminated connectors of each type were removed from the protective containers, were dried overnight, were accessed with a sterile syringe containing 3 mL of sterile trypticase soy broth (BBL, Becton Dickinson), and were flushed with the broth. The injected broth was collected on the downstream side of the intraluminal fluid-pathway in a sterile container, and the number of organisms traversing the septum was enumerated by quantitative culture.

Conventional Disinfection With 70% Alcohol

Ten precontaminated connectors from each manufacturer were disinfected with a vigorous 3-5-second swabbing, using

a sterile commercial pledget of 70% isopropyl alcohol; a fresh pledget was used for each device tested. After disinfection, the connectors were accessed as described above, and the broth was collected on the intraluminal downstream side and cultured quantitatively.

Antiseptic-Barrier Cap

Twenty precontaminated needleless connectors of each manufacturer had the antiseptic cap threaded onto the hub and left in place for 10 minutes. The cap was then removed and, after the septum was allowed to dry, the hub was accessed and flushed as described above, and the broth was captured and cultured.

RESULTS

As seen in the Table, all 15 (100%) of the precontaminated positive control connectors, which were not disinfected before entry, showed transmission of *E. faecalis* across the membranous septum (4,500-10,000 colony-forming units). Of the 30 connectors that were disinfected with 70% alcohol, 20 (67%) showed transmission of *E. faecalis* (442-25,000 colony-forming units). In contrast, of 60 contaminated connectors entered after application of an antiseptic-barrier cap for 10 minutes, only 1 (1.6%) showed any transmission of *E. faecalis* ($P < .001$). None of the 3 negative control connectors tested showed any transmission of microorganisms. The results were very similar for connectors from each of the 3 manufacturers (data not shown).

TABLE. Results of a Simulation Study Comparing the Efficacy of Conventional Disinfection of Heavily Precontaminated Commercial Needleless Connectors With the Efficacy of a Novel Antiseptic-Barrier Cap

Variable	No Disinfection	Disinfection With 70% Alcohol	Disinfection With Antiseptic-Barrier Cap
No. of connectors showing microbial transmission across the membrane /total no. of connectors studied (%)	15/15 (100)	20/30 (67)	1/60 (1.6) ^a
Approximate no. of colony-forming units traversing the membrane	4,500-28,000	442-25,000	0-350

^a $P < .001$.

DISCUSSION

Numerous epidemics of nosocomial BSI have been traced to the entry of microorganisms through the lumen of the catheter into the patient's bloodstream, most often in contaminated infusate,¹ but, in a growing number of recent outbreaks, needleless valve connectors for CVCs appear to have become extrinsically contaminated by microorganisms that traversed the septal membrane to colonize the internal valve structure of the connector.¹⁸⁻²² Unfortunately, there have not been adequate studies to assess the relative contribution of this mechanism of microbial contamination as a cause of *endemic* CVC-related BSI; however, Donlan et al.⁶ have reported that up to 63% of needleless connectors in clinical use showed viable biofilms when sampled randomly. At the present time, there is growing evidence^{23,24} that many US hospitals are experiencing increased rates of nosocomial BSI that appear to be related to the contamination during use of widely used commercial needless systems, particularly long-term central devices, such as cuffed and tunneled catheters or peripherally inserted CVCs.

Our findings suggest that, if there is very heavy contamination of the membranous septum of the needleless connector or injection port, conventional disinfection with 70% alcohol does not reliably prevent entry of microorganisms, which can multiply in the intraluminal fluid column or colonize the internal surface of the valved device, in either instance posing a high risk of intravascular device-related BSI. Our findings show that it is clearly beneficial to disinfect the membranous system of needleless connector or injection ports; however, further studies—ideally, outcome studies that evaluate the effect of different protocols on rates of CVC-associated BSIs³³—are needed to delineate the most effective agents and regimens, with respect to those that can provide the highest level of protection and prevent microbial transmission.

The novel antiseptic-barrier cap studied in this trial was highly effective, essentially sterilizing the membranous septum and almost totally preventing entry of any microorganisms, even with heavy contamination of the septum of a needleless connector. Chlorhexidine has been shown to be a highly effective antiseptic and has been widely used throughout the world for a variety of clinical indications, including disinfection of skin prior to surgery or insertion of intravascular devices, oral care for critically ill hospitalized patients, irrigation of the bladder, and total body bathing of infants. For all of those indications, chlorhexidine has been shown to be safe, and, for cutaneous antiseptics prior to vascular access, has been shown to be safe and superior to povidone-iodine,³³⁻³⁵ and it is now recommended as the cutaneous antiseptic of choice in the most recent guideline of the Centers for Disease Control and Prevention Hospital Infection Control and Practice Advisory Committee.²⁸

In summary, the findings of our study suggest that a perfunctory swab of a needleless membranous septum with al-

cohol to disinfect it before insertion of a needle or male-luer connector may not reliably prevent entry of microorganisms through the device and may not lower the risk of intravascular device-related BSI. The novel antiseptic cap technology studied deserves to be evaluated in a large, multicenter clinical trial with catheter-related BSI as the primary outcome measure.

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