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Universal Intravenous Access Cleaning Device Fails to Sterilize Stopcocks

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BACKGROUND: Contamination of a central venous catheter may occur through use of conventional open-lumen stopcock devices (COLDs), or disinfectable, needleless, closed connectors (DNCCs). We investigated the effectiveness of a new universal IV access cleaning device (Site-Scrub) compared with 70% isopropyl alcohol prep pads for sanitizing COLDs or DNCCs inoculated with common catheter-associated pathogens.

METHODS: Site-Scrub was compared with 70% alcohol prep pads for sanitizing contaminated female Luer lock COLD or DNCC filled with sterile saline or propofol and 2 common bacterial central venous catheter contaminants (*Staphylococcus epidermidis* or *Pseudomonas aeruginosa*). Devices were contaminated using a glove touch (COLD and DNCC) or syringe tip (COLD). The primary end point of the study was colony-forming units (CFU) after 24 hours.

RESULTS: The use of glove touch contamination, the contaminants, *S epidermidis* and *P aeruginosa*, produced CFU in saline-filled COLDs treated with the Site-Scrub, but not in those treated with alcohol pads ($P < 0.001$). Similar results were observed with propofol-filled COLDs ($P < 0.001$). For DNCCs filled with saline or propofol, both alcohol and Site-Scrub effectively reduced CFU growth compared with contaminated controls ($P < 0.001$). When COLDs were contaminated by treated syringe tips, there was no significant evidence of reduction in CFU growth by using either alcohol pads or Site-Scrub compared with contaminated controls.

CONCLUSIONS: These data suggest that when the inner surface of the COLD is contaminated, both alcohol pads and Site-Scrub were not significantly effective in decontaminating the COLD. When the COLD rim is contaminated, however, alcohol pads outperform Site-Scrub. DNCCs were uniformly decontaminated with either treatment. Future work should focus on better access systems because current COLDs are difficult to decontaminate. (Anesth Analg 2014;118:333–43)

Intravascular device-related bloodstream infection is a common source of health care–associated infection, which itself has resulted in increased patient morbidity and mortality.[1] Loftus et al[2] demonstrated that bacterial contamination of conventional open-lumen stopcock device (COLD; Smiths Medical, Dublin, OH) sets occur in up to 32% of cases and is an independent risk factor for increased patient mortality, probably due to infection. Viral and bacterial contaminations of conventional disinfectable, needleless, closed connectors (DNCCs; Baxter Healthcare Corp., Deerfield, IL) have also been associated with increased patient morbidity.[3–7] As such, improvement in intravascular catheter handling is indicated.

A common route to intravascular device–related bloodstream infections is bacterial contamination of the injection port, which leads to hub colonization, intraluminal migration, and distal seeding of the bloodstream. Various methods to attenuate this risk factor, all of which involve treating the interior wall of catheters hubs, COLD, and DNCC with fiber-tipped swabs soaked in 70% alcohol, have been investigated, each of which has achieved moderate success.[8,9] Swabs soaked in 70% isopropyl alcohol have been found ineffective for DNCC disinfection.[9] Recently, the Site-Scrub IPA device[a] (Site-Scrub, CR Bard, Inc., Murray Hill, NJ), a new "universal IV access cleaning device," was introduced, which is claimed to reduce bacterial contamination of COLD and DNCC. The primary aim of this study was to evaluate the relative efficacy of this device as compared with 70% isopropyl alcohol wipes (Medline, Mundelein, IL) in disinfecting COLDs and straight valve DNCCs that have been directly contaminated with potential bacterial pathogens under a variety of laboratory conditions.

METHODS

Overview

This in vitro study was conducted over 4 consecutive months (July to November, 2011) at the clinical microbiology laboratory of Shands Hospital at the University of Florida, Gainesville, FL. The relative efficacy of the Site-Scrub as compared with a 70% isopropyl alcohol wipe for disinfecting COLD and DNCC was evaluated. The primary end point studied was colony-forming units (CFUs) after glove-touch contamination of the COLD and subsequent treatment with

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[a]Site-Scrub IPA device friction. Available at: http://www.bardaccess.com/acc-site-scrub-ipa.php?section=Friction. Accessed April 7, 2013.

the Site-Scrub or alcohol pad in a saline-filled COLD. The secondary end points were the evaluation of DNCC sterilization after glove-touch contamination and COLD sterilization after syringe-tip contamination. Two types of decontamination techniques were compared: one using an alcohol pad versus the other using a Site-Scrub. Four different variables were analyzed and the experimental design is shown in Table 1:

1. Two types of fluid to fill the devices: saline and propofol;
2. Two types of contaminating bacteria: *Staphylococcus epidermidis* and *Pseudomonas aeruginosa*;
3. Two types of devices: DNCC and COLD;
4. Two areas of contamination of the COLD: a rim contamination (derived from a contact glove-touch technique) and an internal contamination (derived from a contaminated syringe technique).

Previously sterile COLDs were injected with 0.25 mL sterile saline (Baxter Healthcare Corp.) or propofol (Diprivan, APP Pharmaceuticals, LLC, Schaumburg, IL) and then directly contaminated with a gloved finger exposed to a 0.5 McFarland standard of *S epidermidis* (ATCC® [American Type Culture Collection, Manassas, VA] 49134) or *P aeruginosa* (ATCC 27853) or indirectly contaminated with a syringe tip exposed to a 0.5 McFarland standard of *S epidermidis* or *P aeruginosa* and subsequently attached to the device. DNCCs were injected with 0.25 mL sterile saline or propofol and then directly contaminated with a gloved finger exposed to identical *S epidermidis* or *P aeruginosa* as per COLD contamination. DNCCs were not contaminated with a syringe tip because they are not designed for this purpose. Devices were then disinfected via a 70% isopropyl alcohol wipe or use of the Site-Scrub after 0, 2, and 24 hours of time had elapsed at ambient conditions.

The methods used were chosen to approximate potential exposure in the clinical environment. Using the glove-touch technique (method shown in Appendix and Appendix Fig. 1), we contaminated the outside of the needleless connector and the rim of the COLD. We also used contaminated syringe tips as a source of device contamination because syringes have been shown to become contaminated after a single use in the clinical environment.[10]

We chose *S epidermidis* as a representative of the *Staphylococcus coagulase* negative group, and *P aeruginosa* as the 2 bacteria for our experiments based on prior data from previous investigations[9,11,12] because they are subsets of resident and transient bacterial flora that have been shown to be transmitted from provider hands to COLD sets or to the surrounding intraoperative environment, including equipment.

Bacterial Contamination and Disinfection of a COLD

Surface Rim Contamination of a COLD

COLDs were taken directly from packaging and accessed using sterile gloves on a sterile surface. Sterile saline or propofol was injected into the fluid cavity of the COLD to fill the dead-space volume of 0.25 mL, then closed at the distal end and one proximal port with the remaining proximal port uncapped. The COLD valve was positioned at a 45° angle between ports to prevent fluid drainage. The index finger of a sterile glove was contaminated with *S epidermidis* (ATCC 49134) or *P aeruginosa* (ATCC 27853) broth via immersion into a 0.5 McFarland standard containing approximately 1.5×10^8 CFU/mL. On contact with the tip of the contaminated index finger of the glove, the injection port rim of the COLD connector was contaminated. For sterile control experiments, the rim was put in contact with a sterile gloved finger not previously contaminated by contact with bacterial broth.

Lumen Contamination of the COLD

The "glove-touch technique" was used to contaminate the tip of a sterile syringe with a 0.5 McFarland solution (1.5×10^8) of *S epidermidis* (ATCC 49134) or *P aeruginosa* (ATCC 27853) made from sterile saline containing approximately 1.5×10^8 CFU/mL. The contaminated syringe was connected to the fluid-filled COLD port and then immediately removed, thus contaminating the intraluminal area of the COLD. For sterile control experiments, the syringe was connected to the fluid-filled COLD port without previous contamination by bacterial broth, followed by immediate removal.

Disinfection of the COLD (After Both Rim and Lumen Contamination)

All COLD ports, including sterile and contaminated controls, were left uncapped and exposed to ambient conditions for 0, 2, and 24 hours before disinfection and sampling. The COLD preparation, after designated drying times (0, 2, 24 hours),

Table 1. Experimental Design for Bacterial Contamination and Disinfection of Either Conventional Open-Lumen Stopcock Devices (*n* = 480) or Disinfectable, Needleless, Closed Connectors (*n* = 480)

Control or treatment	Contaminated control		Sterile control		Ethanol pad treatment		Site-Scrub treatment		Total
Bacteria	*Staphylococcus epidermidis*		*S epidermidis*		*S epidermidis*		*S epidermidis*		
Media	Saline	Propofol	Saline	Propofol	Saline	Propofol	Saline	Propofol	
Time									
0 h	10	10	10	10	10	10	10	10	80
2 h	10	10	10	10	10	10	10	10	80
24 h	10	10	10	10	10	10	10	10	80
Subtotal	30	30	30	30	30	30	30	30	240
Bacteria	*Pseudomonas aeruginosa*		*P aeruginosa*		*P aeruginosa*		*P aeruginosa*		
Media	Saline	Propofol	Saline	Propofol	Saline	Propofol	Saline	Propofol	
Time									
0 h	10	10	10	10	10	10	10	10	80
2 h	10	10	10	10	10	10	10	10	80
24 h	10	10	10	10	10	10	10	10	80
Subtotal	30	30	30	30	30	30	30	30	240
Total	60	60	60	60	60	60	60	60	480

was divided into 4 groups: (1) contaminated control, (2) sterile control, (3) cleaning with an alcohol prep pad (a single swipe across the COLD rim, followed by a 5-second drying period, with the alcohol prep pad cleaning), (4) cleaning with the Site-Scrub according to manufacturer's instructions.[b] Ten COLD replications were performed for each treatment group (alcohol pad and Site-Scrub), contaminated and sterile controls (not a treatment), and drying time (0, 2, and 24 hours). COLD valves were opened and, with the use of a fresh syringe for each stopcock, residual fluid was aspirated and collected in individual sterile holding tubes. The tubes were agitated using a vortex for 5 seconds to ensure uniform distribution of samples for plating at 37°C for 24 hours.

Bacterial Contamination of a DNCC

Each sterile DNCC dead-space volume (0.30 mL) was completely filled with sterile saline or propofol and connected to a stopcock by using a 20-gauge safety IV catheter (Braun Medical Inc., Bethlehem, PA). The lumen of the stopcock attached to the fluid-filled DNCC was then filled with sterile saline (0.2 mL) or propofol (0.2 mL) and then closed.

The injection site surface of the needleless connector was contaminated with a 0.5 McFarland solution of *S epidermidis* and *P aeruginosa* by using the glove-touch technique. After drying for 0, 2, or 24 hours, the DNCC ports were divided into the previously described treatment groups (alcohol pad and Site-Scrub) and contaminated and sterile controls. After treatments were performed, DNCC were penetrated with lever-lock cannulas (Becton Dickinson Infusion Therapy Systems Inc., Sandy, UT), which were connected to sterile syringes, and dead-space fluid was aspirated. Ten DNCC replications were performed for each treatment group (alcohol pad and Site-Scrub), contaminated and sterile controls, and drying time (0, 2, 24 hours). Fluid was collected in sterile individual tubes and agitated on a vortex for plating.

Microbiological Techniques

For both devices (COLD and DNCC), samples for plating were taken by aspirating the fluid from the ports with a syringe. This sampling fluid was then placed in a sterile tube and agitated using a vortex. A sterile, calibrated 10-μL inoculation loop was used to streak sample fluid from the aspirate across standard 5% sheep blood agar plates for determination of CFU. Plates were incubated for 24 hours at 37°C in air. Thereafter, individual colonies were identified and counted. For COLD rim and DNCC contaminations, *P aeruginosa* was diluted to 10 CFU/mL. This was done so that the count could be performed on positive plates due to its larger colony size compared with the solution of *S epidermidis*, in which no dilutions were performed from the original McFarland standard. The McFarland standards were compared with a commercial McFarland standard manufactured by Remel, Inc. (Lenexa, KS) and were read from a MicroScan Turbidity Meter (Dade Behring, West Sacramento, CA). The standards themselves use polystyrene beads in a proprietary buffer and are calibrated versus a BaS04 standard. *P aeruginosa* and *S epidermidis* were both diluted to 10^2 CFU/mL for the contaminated syringe tip trials.

[b]Site-Scrub IPA device features. Available at: http://www.bardaccess.com/acc-site-scrub-ipa.php?section=Features. Accessed April 7, 2013.

Statistical Analysis

The principal outcome of the study was the number of CFUs after glove-touch contamination of the COLD and subsequent treatment with the Site-Scrub applicator or alcohol pad in a saline-filled COLD, as measured at 0 hours. We hypothesized that the Site-Scrub and alcohol pads would reduce the number of CFU from 10 (contaminated control) to 0 (Site-Scrub and alcohol pad) CFU with an estimated SD of 6 CFU. Using α and β values of 0.05 and 0.80, respectively, we estimated that 8 to 10 observations would be required (SigmaPlot 11.2, Systat Software, Inc., San Jose, CA). Thus, we performed 10 replicated observations for each contamination method/connector type/fluid/bacterial species, which resulted in 480 plates examined for CFU count.

CFU data were distributed in a nonparametric manner (Shapiro-Wilk W-statistic), leading to reporting of these data as a box/whiskers plot. After log transformation, CFU data were compared using 2-way, repeated-measures analysis of variance on ranks: factor 1, condition (positive control [contaminated control]; negative control [sterile control]; alcohol pad; Site-Scrub); factor 2, time from disinfection to sampling for plating (with post hoc pairwise comparison using the Holms-Sidak method to correct for multiple comparisons, if appropriate). The secondary outcome of the study was the evaluation of DNCC sterilization after glove-touch contamination and COLD sterilization after syringe-tip contamination. An α of <0.001 was considered statistically significant. To examine further the effectiveness of alcohol pads and Site-Scrub to disinfect the internal lumen of the COLD after contamination with syringe tips, effect sizes of median differences between contaminated controls and alcohol pads/Site-Scrub treatment were quantified with the Hodges-Lehmann estimator.

RESULTS

The results were relatively similar when comparing the types of fluid used and the different contaminating bacteria (saline versus propofol and *S epidermis* versus *P aeruginosa*).

Surface Rim Contamination (Glove Touch) of a COLD

At time 0 hours, the primary end point, alcohol pad treatment was associated with significantly less CFU compared with the contaminated control or Site-Scrub treatment for both bacteria in either saline or propofol (Fig. 1). *S epidermidis* and *P aeruginosa* produced CFU in saline-filled COLD when treated with Site-Scrub or contaminated control treatments (Fig. 1, A and B, $n = 10$ observations/treatment for each bacteria and fluid). No CFU were observed after treatment with an alcohol pad or sterile control. Both the type of COLD treatment ($P < 0.001$ for both bacteria) and time ($P < 0.001$ for both bacteria) affected CFU count for both *S epidermidis* and *P aeruginosa*. Detailed statistical comparisons for treatment of each bacterium are shown in Table 2. Similar to CFU count in the saline data, more CFU were observed in propofol-filled COLD after the contaminated control or Site-Scrub treatment than with alcohol pad decontamination or the sterile control treatment (Fig. 1, C and D, $P = 0.008$ for main treatment effect). Likewise, more CFU were observed during earlier time points ($P < 0.001$). As shown in Appendix Table 1, bacteria were recovered from a significantly larger proportion of

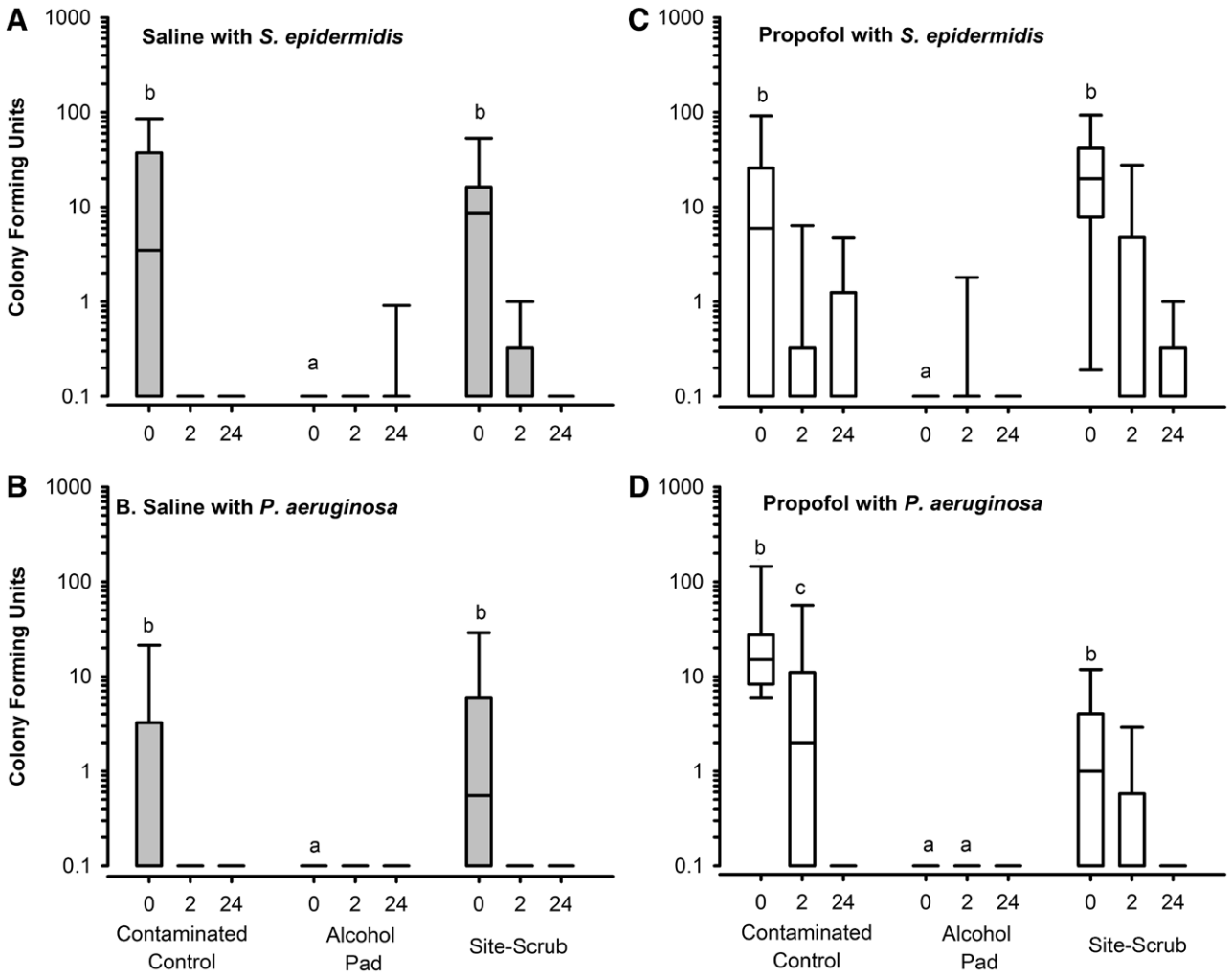


Figure 1. Number of colony-forming units after sampling saline- (A and B) or propofol-filled (C and D) conventional open-lumen stopcock device (COLD) at times 0, 2, and 24 hours after glove-touch contamination (using *Staphylococcus epidermidis* or *Pseudomonas aeruginosa*) and treatment with an alcohol pad, Site-Scrub, or nothing (contaminated control); featured last is a sterile control, uncontaminated with bacteria. Displayed is a box plot (25th/50th/75th percentiles) along with 5th/95th percentile whiskers for 10 observations for each bacteria, syringe-fill, and treatment. $P < 0.05$: [a]alcohol pad at a given time compared with contaminated control or Site-Scrub at the same time; [b]contaminated control or Site-Scrub at 0 hour compared with 2 and 24 hours for the same treatment and COLD fill; [c]2-hour time point compared with 24 hours for a given treatment and COLD fill. Note logarithmic ordinate axis.

COLD when treated with Site-Scrub or the positive-control treatment compared with either those that underwent alcohol pad treatment or the negative control.

Lumen Contamination (Internal Contamination) of the COLD

When COLD were contaminated by treated syringe tips, neither alcohol pads ($P = 0.11$–0.95) nor Site-Scrub ($P = 0.15$–0.96) reduced CFU growth compared with contaminated controls. *S epidermidis* and *P aeruginosa* produced CFU in saline-filled COLD when treated with Site-Scrub, alcohol pad, or contaminated control treatments (Fig. 2, A and B, $n = 10$ observations/treatment for each bacteria and fluid). No CFU were observed after treatment with the sterile control. Both, the type of COLD treatment ($P < 0.001$ for both bacteria) and time ($P < 0.001$ for both bacteria), affected CFU count for both *S epidermidis* and *P aeruginosa*. None of the treatments effectively decontaminated the COLD to values similar to the sterile control ($P < 0.001$). Detailed statistical comparisons for treatment for each bacteria and treatment are shown in Table 3. Similar to CFU count in saline data, more CFU were observed in propofol-filled COLD after the contaminated control or Site-Scrub treatment than with alcohol pad decontamination or the sterile control treatment (Fig. 2, C and D, $P = 0.008$ for main treatment effect). Likewise, more CFU were observed during earlier time points ($P < 0.001$). As shown in Appendix Table 2, bacteria were recovered from a significantly larger proportion of COLD when treated with anything besides the sterile control. The Hodges-Lehmann estimate is the median of all possible paired differences between 2 populations and was used as an effect size estimate of these median differences (contaminated control CFU – alcohol or Site-Scrub CFU), with positive values indicating a reduction in CFU by either alcohol or Site-Scrub treatment and negative values indicating an increase in CFU by either treatment. For saline-filled COLD, effect sizes for median differences in CFU ranged from −14.0 to 10.0 for contaminated controls compared with alcohol pads and ranged from −5.0 to 7.0 for contaminated controls

Table 2. Inferential Comparisons of Different Treatments of Saline or Propofol-Filled Conventional Open-Lumen Stopcocks Device, After Glove-Touch Contamination with *Staphylococcus epidermidis* or *Pseudomonas aeruginosa*

Method	Bacteria	Fluid	Condition 1	Condition 2	*P*
Glove touch	*S epidermidis*	Saline	Site-Scrub	Sterile control	0.005
			Contaminated control	Sterile control	0.010
			Site-Scrub	Alcohol pad	0.010
			Contaminated control	Alcohol pad	0.018
			Alcohol pad	Sterile control	0.899
			Contaminated control	Site-Scrub	0.728
		Propofol	Site-Scrub	Sterile control	0.022
			Contaminated control	Sterile control	0.241
			Site-Scrub	Alcohol pad	0.019
			Contaminated control	Alcohol pad	0.187
			Alcohol pad	Sterile control	1.000
			Contaminated control	Site-Scrub	0.416
	P aeruginosa	Saline	Site-Scrub	Sterile control	<0.001
			Contaminated control	Sterile control	<0.001
			Site-Scrub	Alcohol pad	<0.001
			Contaminated control	Alcohol pad	<0.001
			Alcohol pad	Sterile control	0.731
			Contaminated control	Site-Scrub	0.535
		Propofol	Site-Scrub	Sterile control	<0.001
			Contaminated control	Sterile control	<0.001
			Site-Scrub	Alcohol pad	<0.001
			Contaminated control	Alcohol pad	<0.001
			Alcohol pad	Sterile control	1.000
			Contaminated control	Site-Scrub	<0.001

Ten observations were made for each treatment/bacteria/syringe-fluid combination.
The *P* values for pairwise comparisons for each 2 conditions were corrected using the Holm-Sidak method.

compared with Site-Scrub. For propofol-filled COLD, effect sizes for median differences in CFU ranged from −3.0 to 7.0 for contaminated controls compared with alcohol pads and ranged from 0.0 to 5.0 for contaminated controls compared with Site-Scrub. The multiple comparison adjusted confidence intervals for each of these comparisons cover the lower and upper limits of CFU differences across all pairwise comparisons (Appendix Table 3). For example, the Hodges-Lehmann estimate for the comparison between contaminated controls (*P aeruginosa*) and Site-Scrub treatment (0 hour) in saline-filled COLD was 0.5, with a confidence interval of −27.0 to 27.0. The Hodges-Lehmann estimate thus indicates that the median for all pairwise differences between these groups was a 0.5 reduction in CFU by Site-Scrub, with the lower and upper limits ranging to include both reductions in CFU by Site-Scrub (positive values) and increases in CFU by Site-Scrub (negative values) in pairwise comparisons with contaminated controls. This median difference corresponds to the box and whiskers plot in Figure 2B, which shows a very small difference between the median (0 hour) for the contaminated control and that of the Site-Scrub treatment. This interpretation can be similarly applied to all the Hodges-Lehmann estimates reported in Appendix Table 3. Overall, because the effect size estimates included both positive and negative median differences across the comparisons, these findings failed to find evidence for a consistent pattern of CFU reduction by either alcohol or Site-Scrub treatments as compared with contaminated controls. Moreover, the confidence intervals for all comparisons between contaminated controls and alcohol/Site-Scrub treatments included 0, indicating that the median differences in CFU between these groups did not achieve statistical significance. This corresponds to the findings from the repeated-measures analysis of variance analyses described above.

Contamination of DNCC

In contrast to COLD, the CFU count at 0 hour, the primary end point, was not significantly different under conditions of contaminated control, alcohol pad treatment, or Site-Scrub. Both treatment ($P < 0.001$) and time ($P = 0.026$) affected the CFU count after glove-touch contamination of the saline-filled DNCC injection site. Large numbers of CFU were observed under contaminated control conditions whereas both the alcohol pads and Site-Scrub markedly reduced bacterial growth to rates similar to sterile control conditions. Similar results were noted with propofol-filled DNCC injection sites with respect to treatment ($P < 0.001$) and time ($P < 0.001$), wherein alcohol pad and Site-Scrub administration virtually eliminated bacterial growth. No bacterial colonies were observed when sterile control experiments were performed (Appendix Table 4). Detailed statistical comparisons for treatment of each bacterium are shown in Table 4.

DISCUSSION

In this controlled laboratory investigation, we demonstrated the failure of a newly marketed device (Site-Scrub) to reduce CFU in a contaminated COLD rim. A standard alcohol prep pad, however, was effective in reducing CFU in a similarly contaminated COLD rim. Neither method, however, was significantly effective in disinfecting the internal lumen of the COLD after exposure to a contaminated syringe tip. In contrast, both the Site-Scrub and the alcohol prep pad were effective in disinfecting the surface of the contaminated DNCC.

Interpretation and Recommendations

All health care providers need to pay close attention to possible endoluminal bacterial contamination of intravascular fluid

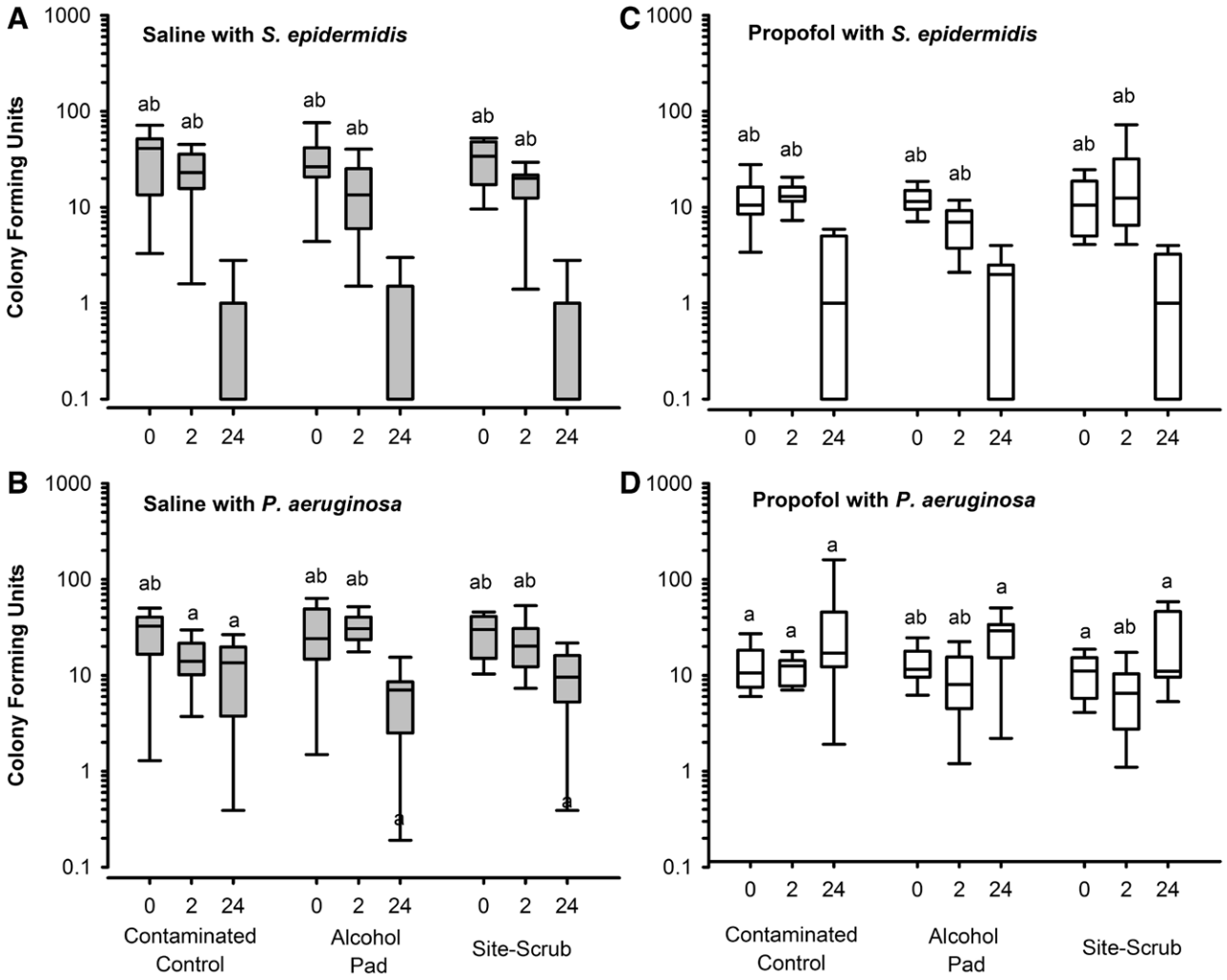


Figure 2. Number of colony-forming units after sampling saline- (A and B) or propofol-filled conventional open-lumen stopcock device C and D), at 0, 2, and 24 hours after syringe-touch contamination (using *Staphylococcus epidermidis* or *Pseudomonas aeruginosa*) and treatment with an alcohol pad, Site-Scrub, or nothing (contaminated control); featured last is a sterile control, uncontaminated with bacteria. Displayed is a box plot (25th/50th/75th percentiles) along with 5th/95th percentile whiskers for 10 observations of each bacteria, syringe-fill, and treatment. $P < 0.05$: [a]compared with sterile control at the same time; [b]compared with 24 hours value for same treatment. Note logarithmic ordinate axis.

pathways. Although the Site-Scrub was a promising solution, unique aspects of this device as we report herein, including the failure to uniformly sterilize contaminated COLD, may explain its suboptimal performance. It is important to remember not to have a false sense of security from unproven, yet marketed, devices designed to address these serious infection problems. Improvements could include both device-related and behavioral interventions. The Healthcare Infection Control Practice Advisory Committee of the Centers for Disease Control has published guidelines for the prevention of catheter-related bloodstream infections (CRBSIs), but there is little detail regarding sterilization of the connection ports during and after access to these sites.[c] However, it is clear from Centers for Disease Control data that maintenance technique, not insertion, is currently the most common source of catheter contamination. Anesthesiologists should be cognizant of the potential for CRBSIs to be caused by contamination of these ports of entry. Loftus et al[13] reported that a frequent source of bacterial contamination of COLD in the operating room is the hands of anesthesia providers. Our data show that after rim contamination, swabbing both COLD and DNCC with an alcohol pad is more effective at eliminating contamination than the use of the Site-Scrub device or no treatment. In our study, DNCCs were easier to decontaminate than COLDs, which makes intuitive sense because when COLDs are contaminated inside the rim they are very difficult to sterilize.

A recent report by Loftus et al[12] showed that there are numerous sources of COLD bacterial contamination, including provider hands, the patient, and most importantly, the anesthesia environment. Therefore, it is very difficult to stop the contamination of the current COLD device, and our data confirm that once contamination occurs, neither the Site-Scrub device nor an alcohol wipe is effective in decontamination.

Observation of Site-Scrub After Use

We reject our primary hypothesis that the Site-Scrub would sterilize central venous catheter access devices and suggest

[c]CDC. Guidelines for the Prevention of Intravascular Catheter-Related Infections, 2011. Available at: http://www.cdc.gov/hicpac/pdf/guidelines/bsi-guidelines-2011.pdf. Accessed December 12, 2013.

Table 3. Inferential Comparisons of Different Treatments of Saline- or Propofol-Filled Conventional Open-Lumen Stopcocks Device, After Syringe-Touch Contamination with *Staphylococcus epidermidis* or *Pseudomonas aeruginosa*

Method	Bacteria	Fluid	Condition 1	Condition 22C	*P*
Syringe touch Touch	*S epidermidis epidermidis*	Saline	Site-Scrub	Sterile control	<0.001
			Contaminated control	Sterile control	<0.001
			Site-Scrub	Alcohol pad	0.774
			Contaminated control	Alcohol pad	0.913
			Alcohol pad	Sterile control	<0.001
			Contaminated control	Site-Scrub	0.944
		Propofol	Site-Scrub	Sterile control	<0.001
			Contaminated control	Sterile control	<0.001
			Site-Scrub	Alcohol pad	0.822
			Contaminated control	Alcohol pad	0.948
			Alcohol pad	Sterile control	<0.001
			Contaminated control	Site-Scrub	0.957
	P aeruginosa	Saline	Site-Scrub	Sterile control	<0.001
			Contaminated control	Sterile control	<0.001
			Site-Scrub	Alcohol pad	0.380
			Contaminated control	Alcohol pad	0.110
			Alcohol pad	Sterile control	<0.001
			Contaminated control	Site-Scrub	0.382
		Propofol	Site-Scrub	Sterile control	<0.001
			Contaminated control	Sterile control	<0.001
			Site-Scrub	Alcohol pad	0.185
			Contaminated control	Alcohol pad	0.938
			Alcohol pad	Sterile control	<0.001
			Contaminated control	Site-Scrub	0.148

Ten observations were made for each treatment/bacteria/syringe-fluid combination.
The *P* values for pairwise comparisons for each 2 conditions were corrected using the Holm-Sidak method.

Table 4. Inferential Comparisons of Different Treatments of Saline or Propofol-Filled Disinfectable, Needleless, Closed Connectors, After Glove-Touch Contamination with *Staphylococcus epidermidis* or *Pseudomonas aeruginosa*

Method	Bacteria	Fluid	Condition 1	Condition 2	*P*
Glove touch	*S epidermidis*	Saline	Site-Scrub	Sterile control	0.499
			Contaminated control	Sterile control	<0.001
			Site-Scrub	Alcohol pad	0.369
			Contaminated control	Alcohol pad	<0.001
			Alcohol Pad	Sterile control	1.000
			Contaminated control	Site-Scrub	<0.001
		Propofol	Site-Scrub	Sterile control	1.000
			Contaminated control	Sterile control	<0.001
			Site-Scrub	Alcohol pad	1.000
			Contaminated control	Alcohol pad	<0.001
			Alcohol pad	Sterile control	1.000
			Contaminated Control	Site-Scrub	<0.001
	P aeruginosa	Saline	Site-Scrub	Sterile control	0.970
			Contaminated control	Sterile control	<0.001
			Site-Scrub	Alcohol pad	0.904
			Contaminated control	Alcohol pad	<0.001
			Alcohol pad	Sterile control	1.000
			Contaminated control	Site-Scrub	<0.001
		Propofol	Site-Scrub	Sterile control	0.870
			Contaminated control	Sterile control	<0.001
			Site-Scrub	Alcohol pad	0.744
			Contaminated control	Alcohol pad	<0.001
			Alcohol pad	Sterile control	1.000
			Contaminated control	Site-Scrub	<0.001

Ten observations were made for each treatment/bacteria/syringe-fluid combination.
The *P* values for pairwise comparisons for each 2 conditions were corrected using the Holm-Sidak method.

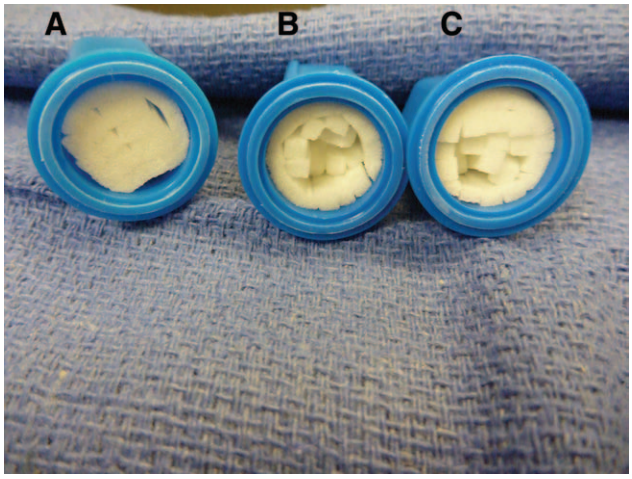


Figure 3. The Site-Scrub device before use (A) and after use (B and C) with a conventional open-lumen stopcock device.

a possible explanation for this unexpected result based on direct observation. The Site-Scrub, which consists of a plastic thimble housing foam bristles containing 70% isopropyl alcohol and 5% chlorhexidine, does not uniformly extend down into the COLD during use (Fig. 3). We observed that Site-Scrub devices (Fig. 3A) possessed bristles that were frequently compressed and disordered (Fig. 3B and 3C) following engagement into a COLD. With this frequent occurrence, it appeared that the bristles of the foam might not contact and sterilize bacteria in the inner rim of the COLD. Figure 3C shows an instance wherein the bristles of the Site-Scrub, after engagement into the COLD, emerged elongated.

Limitations

Several experimental conditions limit interpretations of this investigation's results. First, the study was conducted in a controlled laboratory environment to limit the number of variables to those directly relevant to the hypothesis. These experiments, however, have not been replicated in the clinical environment to assess the validity of the hypothesis. Nevertheless, we can find no data to suggest that the hypothesis is not also evidenced in the clinical environment. Second, we tested only 2 pathogens. Although we chose bacteria species based on prior investigations and believe they represent clinically important pathogens, many different organisms cause CRBSIs. We do not know whether these results also apply to these untested bacteria. Third, the DNCCs used are split-septum valve in design. It has been shown that these connectors have lessened the incidence of infection compared with the mechanical valve needleless designs. Fourth, the Site-Scrub may show better efficacy in vivo, where biofilms may form on the inside of the COLD. We did not allow time for possible biofilms to form.

Conclusions

When the inner part of the COLD is contaminated, neither the alcohol pad nor the Site-Scrub are significantly effective. When the outer rim is contaminated, both are effective, with the Site-Scrub decontamination device being inferior to the alcohol pad and to the control. DNCCs are decontaminated equally well with either cleaning technique. Future work should focus on better access systems and decontamination techniques as current COLD are difficult to decontaminate.

APPENDIX

VALIDATION OF THE GLOVE-TOUCH METHOD

In a sterile environment, 1 of the 2 female access sites of a conventional open-lumen stopcock device (COLD) was uncapped after direct removal from the packaging material. The index finger of a sterile gloved hand was dipped into the broth of a previously prepared 0.5 McFarland standard diluted to 10, 10^2, 10^3, or 10^4 colony-forming units (CFU)/mL, containing either *StaphylococcuS epidermidis* or *Pseudomonas aeruginosa*.

We also contaminated the rims of sterile, saline-filled COLDs. The rims were touched with the tip of the index finger of the sterile glove, which had been dipped into a bacterial broth composed of the abovementioned dilutions (10^{-1}, 10^{-2}, 10^{-3}, or 10^{-4}) and bacteria types *S epidermidis*

Appendix Table 1. Number of Contaminated Conventional Open-Lumen Stopcock Devices, Using the Glove-Touch Method, After a Given Treatment, from a Total of 10 Experiments, per Bacteria, for a Given Condition

Fluid	Bacteria	Time (h)	Treatment				
			Contaminated control	Alcohol pad	Site-Scrub	Sterile control	
Saline							
	Staphylococcus epidermidis	0	7	0	6	0	*a*
		2	0	0	2	0	
		24	0	1	0	0	
	Pseudomonas aeruginosa	0	3	0	5	0	*a*
		2	0	0	0	0	
		24	0	0	0	0	
Propofol							
	S epidermidis	0	7	0	9	0	*a*
		2	2	1	3	0	
		24	3	0	2	0	
	P aeruginosa	0	10	0	6	0	*a*
		2	6	0	2	0	
		24	0	0	0	0	

[a]Treatment significantly affected the number of positive cultures.

Appendix Table 2. Number of Contaminated Conventional Open-Lumen Stopcock Devices, Using the Syringe-Touch Method, After a Given Treatment, from a Total of 10 Experiments, per Bacteria, for a Given Treatment

Fluid	Bacteria	Time (h)	Condition				
			Contaminated control	Alcohol pad	Site-Scrub	Sterile control	
Saline							
	Staphylococcus epidermidis	0	10	10	10	0	*a*
		2	9	10	10	0	*a*
		24	3	4	4	0	*a*
	Pseudomonas aeruginosa	0	9	9	10	0	*a*
		2	10	10	10	0	*a*
		24	9	9	9	0	*a*
Propofol							
	S epidermidis	0	10	10	10	0	*a*
		2	10	10	10	0	*a*
		24	7	7	7	0	*a*
	P aeruginosa	0	10	10	10	0	*a*
		2	10	10	10	0	*a*
		24	10	10	10	0	*a*

[a]Treatment significantly affected the number of positive cultures.

Appendix Table 3. Effect Sizes of Median Differences for CFU, as Indexed by the Hodges-Lehmann Estimator, for Comparison of Different Treatments of Saline or Propofol-Filled COLD After Syringe-Touch Contamination with *Staphylococcus epidermidis* or *Pseudomonas aeruginosa*

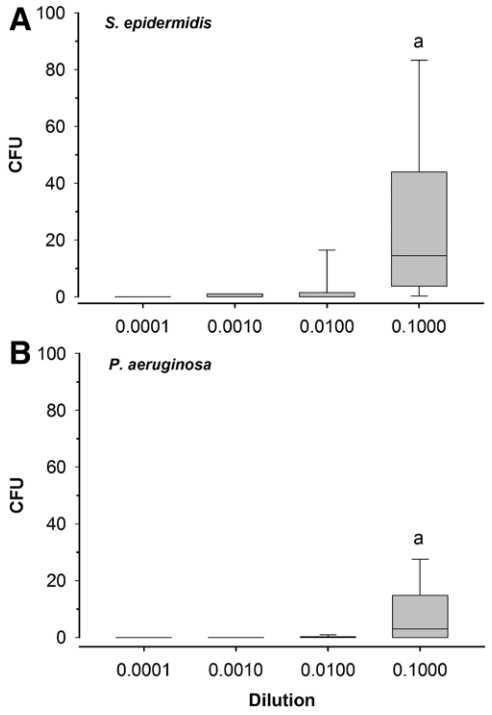
Bacteria	Fluid	Condition 1	Condition 2	Effect size of median difference[a]		
				0 h[b]	2 h	24 h
S epidermidis	Saline	Contaminated	Alcohol	10.0 (−36.0 to 44.0)	9.0 (−19.0 to 32.0)	0.0 (−3.0 to 1.0)
		Contaminated	Site-Scrub	6.0 (−32.0 to 39.0)	7.0 (−14.0 to 26.0)	0.0 (−1.0 to 1.0)
	Propofol	Contaminated	Alcohol	−1.0 (−8.0 to 10.0)	7.0 (0.0 to 14.0)	0.0 (−3.0 to 5.0)
		Contaminated	Site-Scrub	0.5 (−13.0 to 12.0)	1.0 (−56.0 to 11.0)	0.0 (−3.0 to 5.0)
P aeruginosa	Saline	Contaminated	Alcohol	2.0 (−34.0 to 32.0)	−14.0 (−33.0 to 2.0)	7.0 (−6.0 to 19.0)
		Contaminated	Site-Scrub	0.5 (−27.0 to 27.0)	−5.0 (−34.0 to 11.0)	3.5 (−11.0 to 17.0)
	Propofol	Contaminated	Alcohol	−1.0 (−11.0 to 11.0)	2.0 (−9.0 to 11.0)	−3.0 (−29.0 to 117.0)
		Contaminated	Site-Scrub	2.0 (−8.0 to 14.0)	5.0 (−4.0 to 12.0)	4.5 (−40.0 to 110.0)

CFU = colony-forming units; COLD = conventional open-lumen stopcock device.
[a]Hodges-Lehmann estimator (contaminated control CFU − alcohol or Site-Scrub CFU) with 99.9% confidence interval given in parentheses.
[b]Time after syringe-touch contamination.

Appendix Table 4. Number of Contaminated Disinfectable, Needleless, Closed Connectors, Using the Glove–Touch Method, After a Given Treatment, from a Total of 10 Experiments, per Bacteria, for a Given Treatment

Fluid	Bacteria	Time (h)	Condition				
			Contaminated control	Alcohol pad	Site-Scrub	Sterile control	
Saline							
	Staphylococcus epidermidis	0	10	0	2	0	*a*
		2	6	0	0	0	*a*
		24	6	0	1	0	*a*
	Pseudomonas aeruginosa	0	10	0	0	0	*a*
		2	4	0	0	0	*a*
		24	0	0	0	0	
Propofol							
	S epidermidis	0	10	0	0	0	*a*
		2	5	0	0	0	*a*
		24	8	0	1	0	*a*
	P aeruginosa	0	10	0	0	0	*a*
		2	4	0	0	0	*a*
		24	0	0	1	0	

[a]Treatment significantly affected the number of positive cultures.



Appendix Figure 1. Validation of glove-touch technique to contaminate a conventional open-lumen stopcock device. Displayed are colony-forming units (CFUs) for serial dilutions of *StaphylococcuS epidermidis* (A) or *Pseudomonas aeruginosa* (B). Data expressed as box plots (25th/50th/75th percentiles) along with 5th/95th percentile whiskers for 10 observations for each bacteria at a given dilution. $P < 0.05$: [a]compared with all other dilutions.

or *P aeruginosa*. With no drying time (0 hour), the saline was aspirated from the COLD by using a sterile syringe and then placed in sterile holding tubes and vortexed to ensure uniform sampling. An aliquot was then taken from each holding tube by using a 10-µL inoculation loop and streaked over blood agar plates. CFU were counted with 10 replicates for each dilution and bacteria type. The results of this method validation are shown in Figure A.

DISCLOSURES

Name: Julie L. Holroyd.
Contribution: This author helped design and conduct the study, analyze the data, and write the manuscript.
Attestation: Julie L. Holroyd has seen the original study data, reviewed the analysis of the data, and approved the final manuscript.
Name: David A. Paulus, MD.
Contribution: This author helped design and conduct the study, analyze the data, and write the manuscript.
Attestation: David A. Paulus has seen the original study data, reviewed the analysis of the data, and approved the first revision of the manuscript.
Name: Kenneth H. Rand, MD.
Contribution: This author helped analyze the data and write the manuscript.
Attestation: Kenneth H. Rand has seen the original study data, reviewed the analysis of the data, and approved the final manuscript.
Name: F. Kayser Enneking, MD.
Contribution: This author helped interpret the data and write the manuscript.
Attestation: F. Kayser Enneking has seen the original study data and approved the final manuscript.
Name: Timothy E. Morey, MD.
Contribution: This author helped design the study, analyze the data, and write the manuscript.
Attestation: Timothy E. Morey has seen the original study data, reviewed the analysis of the data, approved the final manuscript, and is the author responsible for archiving the study files.
Name: Mark J. Rice, MD.
Contribution: This author helped design and conduct the study, analyze the data, and write the manuscript.
Attestation: Mark J. Rice has seen the original study data, reviewed the analysis of the data, and approved the final manuscript.
This manuscript was handled by: Sorin J. Brull, MD, FCARCSI (Hon).

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REFERENCES

1. Edwards JR, Peterson KD, Mu Y, Banerjee S, Allen-Bridson K, Morrell G, Dudeck MA, Pollock DA, Horan TC. National Healthcare Safety Network (NHSN) report: data summary for 2006 through 2008, issued December 2009. Am J Infect Control 2009;37:783–805
2. Loftus RW, Koff MD, Burchman CC, Schwartzman JD, Thorum V, Read ME, Wood TA, Beach ML. Transmission of pathogenic bacterial organisms in the anesthesia work area. Anesthesiology 2008;109:399–407
3. Danzig LE, Short LJ, Collins K, Mahoney M, Sepe S, Bland L, Jarvis WR. Bloodstream infections associated with a needleless intravenous infusion system in patients receiving home infusion therapy. JAMA 1995;273:1862–4
4. Kellerman S, Shay DK, Howard J, Goes C, Feusner J, Rosenberg J, Vugia DJ, Jarvis WR. Bloodstream infections in home infusion patients: the influence of race and needleless intravascular access devices. J Pediatr 1996;129:711–7
5. Cookson ST, Ihrig M, O'Mara EM, Denny M, Volk H, Banerjee SN, Hartstein AI, Jarvis WR. Increased bloodstream infection rates in surgical patients associated with variation from recommended use and care following implementation of a needleless device. Infect Control Hosp Epidemiol 1998;19:23–7
6. McDonald LC, Banerjee SN, Jarvis WR. Line-associated bloodstream infections in pediatric intensive-care-unit patients

[d]FMA Tribute to David A. Paulus, M.D. Available at: http://www.youtube.com/watch?v=iaXilE3I3dA. Accessed December 12, 2013.

associated with a needleless device and intermittent intravenous therapy. Infect Control Hosp Epidemiol 1998;19:772–7
7. Arduino MJ, Bland LA, Danzig LE, McAllister SK, Aguero SM. Microbiologic evaluation of needleless and needle-access devices. Am J Infect Control 1997;25:377–80
8. Salzman MB, Isenberg HD, Rubin LG. Use of disinfectants to reduce microbial contamination of hubs of vascular catheters. J Clin Microbiol 1993;31:475–9
9. Menyhay SZ, Maki DG. Disinfection of needleless catheter connectors and access ports with alcohol may not prevent microbial entry: the promise of a novel antiseptic-barrier cap. Infect Control Hosp Epidemiol 2006;27:23–7
10. Blogg CE, Ramsay MA, Jarvis JD. Infection hazard from syringes. Br J Anaesth 1974;46:260–2
11. Knobben BA, van der Mei HC, van Horn JR, Busscher HJ. Transfer of bacteria between biomaterials surfaces in the operating room–an experimental study. J Biomed Mater Res A 2007;80:790–9
12. Loftus RW, Brown JR, Koff MD, Reddy S, Heard SO, Patel HM, Fernandez PG, Beach ML, Corwin HL, Jensen JT, Kispert D, Huysman B, Dodds TM, Ruoff KL, Yeager MP. Multiple reservoirs contribute to intraoperative bacterial transmission. Anesth Analg 2012;114:1236–48
13. Loftus RW, Muffly MK, Brown JR, Beach ML, Koff MD, Corwin HL, Surgenor SD, Kirkland KB, Yeager MP. Hand contamination of anesthesia providers is an important risk factor for intraoperative bacterial transmission. Anesth Analg 2011;112:98–105