Comparison of Bacterial Transfer and Biofilm Formation on Intraluminal Catheter Surfaces Among Fourteen Connectors in a Clinically Simulated in vitro Model

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INTRODUCTION

The use of needleless connectors is an important strategy in the prevention of needlestick injuries for healthcare workers and caregivers of patients with vascular access devices. The design components of the connector influence the potential for bacteria to pass from the connector surface into the flow path of the connector, catheter hub and catheter lumen. Intraluminal biofilm is a predominant source of catheter-related bloodstream infection (CRBSI) during the maintenance phase of catheterization.

PURPOSE

The purpose of this study was to compare the bacterial transfer rate of fourteen needleless connectors through the connector-catheter system and to compare biofilm formation within the connectors, catheter hubs, and catheter lumens.

METHODS

A total of 14 needleless connector designs were evaluated in this study. Three of each connector type were evaluated in three replicate runs (n=9) with the MicroClave® serving as the matched control for every run in a total of 21 runs.

MicroClave® ICU Medical, Inc.

TKO®-6 Nexus Medical

Bionector® Vygon SA

MaxPlus® CareFusion Corporation

Biosite® Lily Medical Corporation

Neutron® ICU Medical, Inc.

Caresite® B. Braun Medical, Inc.

One-Link® Baxter International, Inc.

ClearLink® Baxter International Inc.

Q-Syte™ BD and Co.

InVison® Plus Rymed Technologies, LLC

SmartSite® CareFusion Corporation

Kendall™ Covidien

UltraSite® B. Braun Medical, Inc.

The connector septum was inoculated twice a day with approximately 10^6 CFU *Staphylococcus aureus* ATCC # 6538. The inoculated connector was allowed to dry for 30 minutes and then was attached to a 50cm PICC polyurethane catheter.

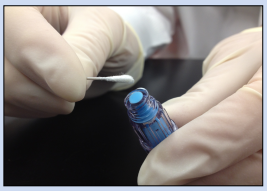

Figure 2. For surface inoculation controls, the connector was swabbed in order to determine the concentration of bacteria on the connector septum.

Each connector-catheter set was flushed with 3.0 ml sterile saline which was collected and plated (*First Flush*). The catheter-connector sets were sterile normal saline (NS) flushed twice more, locked with sterile Brain Heart Infusion Broth (BHI) for 1 hour and NS flushed three more times. The last flush was also collected and plated (*Last Flush*).

METHODS (cont.)

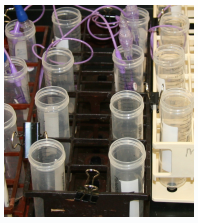

Figure 2. The connector-catheter sets were placed in conical Vials between flushes. The technician is flushing one of the Connector-catheter sets.

The connector-catheter sets were inoculated a second time each day after the 6th sterile saline flush followed by a second round of flushing, plating and locks for a total of 18 connector accesses daily, considered to be a routine number of accesses in an intensive care unit.

The entire procedure, inoculation and flushing, was repeated each day for 5 days. On Days 4 and 5, two connector-catheter sets for each connector type were destructively sampled for bacterial counts and microscopy.

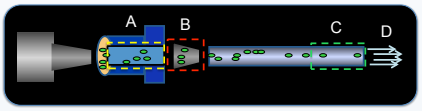

Figure 3. Schematic of the destructive sampling for biofilm analysis. A. connector, B. catheter hub, C. catheter segment, D. flush solution

Statistical analysis was performed using mixed effect ANOVA and Tukey's tests to determine significant mean differences of log density of bacteria in the flush, hub, catheter segment or connector amongst the different needle-free connectors. A multiple linear regression was used to determine if any combination of the log density of bacteria in the connector, hub, or catheter segment could significantly predict the log density of bacteria in the flush.

RESULTS

The MicroClave and Neutron connectors had statistically significantly smaller mean log densities (LD) of bacteria in the flush, when pooled over all flushes, inoculations, days, and runs, compared to any other of the connector types p <0.0023). The MicroClave and Neutron were not statistically significantly different (p = 1.0)

The Q-Syte and UltraSite had the significantly largest mean LDs of bacteria in the flush compared to any of the other connector types. (p <0.0024). The Q-Syte and UltraSite were not statistically significantly different (p = 0.9101).

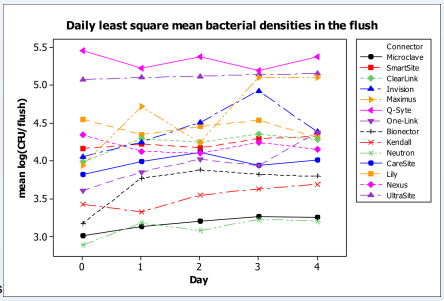

Table 1. A comparison of the daily least square mean LD per flush amongst the connector types over the 96 hour test period.

Flush

Connector	Least Square Mean log(CFU/flush)[6]	Significant Groups
Neutron	3.115	A
MicroClave	3.171	A
Kendall	3.523	B
Bionector	3.686	B C
One-Link	3.957	C D
Caresite	3.973	C D
TKO-6	4.192	D E
ClearLink	4.229	D E F
SmartSite	4.232	D E F
Invision Plus	4.423	E F
Biosite	4.437	E F
MaxPlus	4.619	F
UltraSite	5.114	G
Q-Syte	5.321	G

Table 2. The least square mean for all flushes for all days was calculated. The color scheme indicates the significant groups (p< 0.05).

RESULTS (cont.)

Connector

Connector	least square mean log(CFU/connector)	Significant Groups
MicroClave	2.487	A
One-Link	2.557	A B
Neutron	2.892	A B C
ClearLink	2.958	A B C D
SmartSite	3.217	A B C D E
Kendall	3.435	B C D E F
Bionector	3.450	C D E
TKO-6	3.483	B C D E
Invision Plus	3.725	B C D E F
MaxPlus	3.893	C D E F
Q-Syte	3.939	C D E F
Biosite	4.134	D E F
Caresite	4.355	E F
UltraSite	4.673	F

Table 3. The least square mean for the destructive sampling of the connectors was calculated for Days 3 and 4 combined. The color scheme indicates the significant groups (p< 0.05).

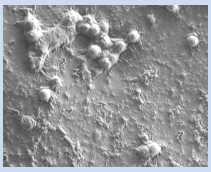

Figure 4. Biofilm colony on the septum of a needleless connector after 96 hours.

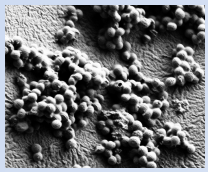

Figure 5. Biofilm formation on the intraluminal surface in the flowpath of the needleless connector in Figure 4. The bacteria were transferred into the connector on access with the flush syringe.

Hub

Connector	least square mean log(CFU/hub)	Significant Groups
Neutron	1.383	A
Kendall	1.645	A B C
MicroClave	1.915	A B
One-Link	2.039	A B C D
ClearLink	2.184	A B C D F
TKO-6	2.369	A B C D F G
SmartSite	2.415	A B C D F G
MaxiPlus	2.474	A B C D F G
Biosite	2.582	B C D F G H
UltraSite	2.723	C D F G H
Caresite	2.978	D F G H
Bionector	3.254	F G H
Q-Syte	3.311	F G H
Invision Plus	3.451	G H

Table 4. The least square mean for the destructive sampling of the catheter hubs was calculated for Days 3 and 4 combined. The color scheme indicates the significant groups (p< 0.05)

Catheter Segment

Connector	least square mean log(CFU/segment)	Significant Groups
Neutron	0.660	A B
Kendall	0.698	A B
Biosite	0.764	A B
MicroClave	0.810	A
One-Link	1.144	A B C
ClearLink	1.175	A B C
TKO-6	1.180	A B C
MaxPlus	1.472	A B C
Invision Plus	1.492	B C
SmartSite	1.545	B C
UltraSite	1.554	B C
Bionector	1.655	C
Q-Syte	1.863	C
Caresite	1.894	C

Table 5. The least square mean for the destructive sampling of the catheter segments was calculated for Days 3 and combined. The color scheme indicates the significant groups (p< 0.05).

DISCUSSION

The risk of transfer of bacteria through the connector, hub and catheter lumen and into the bloodstream from a contaminated connector surface is dependent on the type of connector used. The results of this study validates that biofilm formation in the catheter hub and internal lumen can result from bacterial transfer through a needleless connector. It further demonstrates that detached or planktonic bacteria shed from the biofilm are subsequently flushed into the bloodstream with infusion.

Regression analysis indicates that biofilm formation within the connector was the best predictor of the number of bacteria flushed into the bloodstream ($R\text{-squared}=95\%$). Thus the use of a connector with a low microbial transfer rate may minimize the risk of bloodstream infection. It also points to the use of consistent and effective disinfection methods of the connector and catheter hub prior to access as a critical strategy for prevention of CRBSI. The data also suggests that the common classification related to features of connectors such as split septum and mechanical valve is an unreliable approach for device selection based on infection risk.

CONCLUSIONS

- The risk of transfer of bacteria from a contaminated connector surface through the hub and catheter lumen and into the bloodstream is dependent on the type of connector used. The MicroClave and Neutron had a significantly lower bacterial transfer rate than any of the other connectors.
- Biofilm formation in the catheter hub and internal lumen can result from bacteria transferred through a needlefree connector.
- Biofilm formation within the connector is a good predictor of the number of bacteria flushed into the bloodstream.
- The frequency of connector exchange may be dependent on the bacterial transfer potential of each device design.
- The common classification of split septum and mechanical valve is an over-simplification and an unreliable approach for device selection based on infection risk.