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Major Article

Microbial colonization of intravascular catheter connectors in hospitalized patients

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Background: Central line–associated bloodstream infections may be due to catheter connector colonization and intraluminal migration of pathogens. We assessed the colonization of the split septum catheter connector system, and subsequently the luer lock catheter connector system.

Methods: This was a prospective, 2 phase, quality improvement study at a tertiary referral center. Each phase of the study was performed over 3 consecutive days in hospitalized patients receiving an active infusion; first with a split septum lever lock connector and second with a luer lock connector and alcohol port protector. The connectors were inoculated onto blood agar plates and incubated. Plates were assessed for microbial growth after 48-72 hours.

Results: In phase I, 98 (41.9%) of 234 split septum connectors yielded microbial growth. In phase II, 56 (23.1%) of 243 luer lock connectors yielded microbial growth. In phase II only, there was a significant increased rate of contamination in peripheral catheters compared with all other catheters, and the rate of contamination on the acute care wards was significantly higher when compared with the intensive care units.

Conclusions: Bacterial colonization of the lever lock system was unacceptably high among all catheter types and hospital locations. Transition to luer lock catheter connectors and alcohol port protectors decreased the colonization; however, colonization still remained substantial. Causation of colonization cannot be determined with these results.

Central line–associated bloodstream infections (CLABSIs) are reportable events that have been shown in multiple studies to increase patient morbidity and mortality, length of stay, and hospital and patient costs; thus, ongoing evaluations of methods to reduce CLABSI rates remains necessary.[1,2] CLABSIs occur through 2 main mechanisms: via extraluminal spread of bacteria along the surface of the catheter into the bloodstream or through intraluminal spread of bacteria from contamination of connectors. Historically, extraluminal contamination was the most common etiology, thus many efforts were directed toward prevention of this mechanism (insertion bundles, chlorhexidine skin preparation, chlorhexidine impregnated dressings).[2] However, recent data suggests CLABSI may be more frequently associated with intraluminal contamination.[3,4]

In the United States, needleless catheter connectors are universally used to decrease the risk of needlestick injuries.[5] There is great variation in design of needleless connectors and some have been associated with an increased risk of infection.[6-9] Colonization of the catheter connectors is a significant source of contamination and a potential contributor to CLABSIs via intraluminal spread of bacteria.[10-12] Colonization of the connector likely occurs after the intravenous (IV) catheter has been placed, owing to the catheter connector being manipulated in the course of care for patients.

Previously, we demonstrated that the lever lock split septum connector in use at our hospital was easily disinfected with a 5 second scrub with an alcohol pad.[13] However, the lever lock split septum connectors may theoretically develop bacterial contamination during active patient care owing to the unprotected, open interface of the locking mechanism (Fig 1). To determine the rate of contamination, we first assessed the contamination of the lever lock split septum (referred to going forward as 'split septum') and then repeated the process with a mechanical luer lock connector (referred to going

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forward as 'luer lock') in conjunction with alcohol impregnated port protectors.

METHODS

The study took place at a 689-bed tertiary care, academic hospital. The local institutional review board approved the project with a waiver of informed consent. A prospective survey was performed twice, approximately 1 year apart, throughout intensive care units (ICUs) and acute care wards over 3 consecutive days in adult patients receiving an active IV infusion. The first phase was performed in 2016, while split septum IV connectors (Lever Lock, Becton Dickinson, Franklin Lakes, NJ) were being used. The same process was followed in 2017, 3 months after introduction of luer lock IV connectors (Max-Zero, Becton Dickinson) with passive alcohol port protectors (Curos, 3M, Maplewood, MN). The 3-month washout period was chosen to ensure all luer lock connectors were in place and nursing education on use was completed. There were no changes to infection control procedures or nursing protocol for catheter management during both phase I and phase II. Nursing staffing ratios were unchanged from phase I to phase II with 2:1 and 3:1 ratios in ICUs and 4:1 ratios on general medical and surgical wards. Lists were obtained of all the patients in the hospital with central venous catheters to efficiently find central venous catheter connectors in the hospital and prioritize unit choice for convenience sampling. No patient-identifying information was gathered, and patients, in-room visitors, and nurses were informed of the project. Only patients receiving active IV infusions were included in the study. A physician analyzed these infusions and if they were antimicrobials or critical infusions, that could not be interrupted safely (eg, pressors, antiarrhythmics), they were excluded. The connectors (Figs. 1 and 2) were sampled by interrupting the infusion, disconnecting the IV connector, and pressing the diaphragm of the connector onto blood agar plates. Each diaphragm of the connector was placed on the agar plate 4 times as previously described.[13] After the catheter connector was sampled, it was cleaned with an alcohol swab for 5-10 seconds, and then it was reconnected to the infusion. After reconnecting the catheter connector, the noncritical infusion was restarted. Each plate was documented regarding whether the catheter was peripheral or central, along with the type of IV tubing that was attached. Three different investigators participated in disconnecting the IV connectors and plating the catheter connector on the agar plates after standardized training. A research coordinator was present throughout both studies to ensure consistency and quality of data collection. Sterility controls were not performed.

The blood agar plates were incubated at 37°C and assessed for growth characteristics after 48-72 hours by 2 investigators. The investigators assessed the plates concurrently to assess the growth of each plate, agreeing on the extent of growth. Each catheter connector quadrant was assessed and recorded as exhibiting no growth, <15 separate colony forming units (CFUs), >15 CFUs, or confluent growth along the entire catheter connector diaphragm impression in the agar. Each catheter connector culture plate was also assessed for similarity of colony morphology and whether the growth appeared to be mono- or polymicrobial (Fig 3).

Fig 1. Lever lock split septum catheter connector system.

Fig 2. Mechanical luer lock catheter connector system.

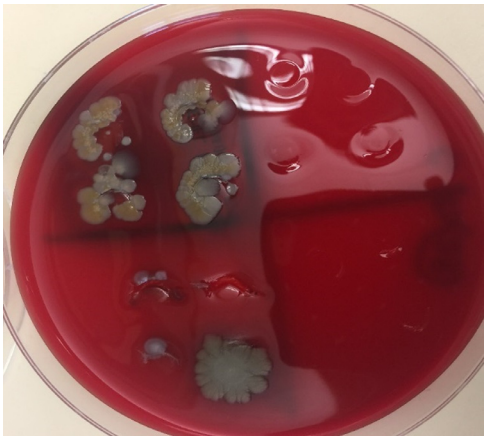

Fig 3. Agar plate with positive growth (the 4 samples per connector per plate quadrant is clearly evident).

A descriptive report of the types of bacteria present via plate review was performed by the Nebraska Medicine Clinical Microbiology Laboratory Director.

Statistical analysis

Data were presented as counts and percentages. The Fisher exact test was used to look at associations between catheter type and culture results. A P value of <.05 was considered statistically significant. All analyses were generated using SAS software, Version 9.4 (SAS Institute, Cary, NC).

RESULTS

A total of 234 catheter connectors were cultured in phase I with the split septum connectors, and 243 catheter connectors were cultured in phase II with the luer lock connectors. During the assessment of phase I, 85 catheters were internal jugular venous catheters, 57 were peripherally inserted central catheters, 52 were peripheral IV catheters (PIV), 33 were central catheters inserted at alternative locations (femoral, subclavian, etc), and 7 did not have a catheter type documented. A total of 134 catheter connectors were cultured from patients located on ICUs, and 100 were from general medical/surgical

Table 1
Culture comparison of intravascular catheter connectors

Variable	Phase I	Phase II	*P* Value
Overall cultures, n (%)	234	243	
Positive	98 (41.9)	56 (23.1)	<.0001
Intensive care units, n (%)			
Overall cultures	134	173	
Positive cultures	52 (38.8)	33 (19.1)	<.0002
General ward,* n (%)			
Overall cultures	100	70	
Positive cultures	46 (46.0)	23 (32.9)	.11
Intravascular line type, n (%)			
Peripheral	52	93	
Positive cultures	26 (50.0)	28 (30.1)	.02
PICC	57	68	
Positive cultures	21 (36.8)	16 (23.5)	.08
CVC	85	59	
Positive cultures	27 (31.8)	9 (15.3)	.03
Other	40	23	
Positive cultures	24 (60.0)	3 (13.0)	.001

Phase I, split septum connectors; Phase II, luer lock connectors.
CVC, centrally inserted venous catheter; *PICC*, peripherally inserted central catheter.
*General ward included medical and surgical units.

floors. Of the 134 cultures from patients located in ICUs, 52 of them were positive (38.8%), and there were 46 positive cultures taken from patients located on general medical/surgical wards (46%). A total of 98 (41.9%) connectors yielded microbial growth. There was no significant difference in the rate of contamination when comparing clinical unit or catheter type in phase I.

In phase II, 243 catheter connectors were assessed. A total of 59 were internal jugular venous catheters, 68 were peripherally inserted central catheters, 93 were PIVs, and 23 were from other locations (subclavian, femoral, and transhepatic). A total of 173 were cultured from catheter connectors of patients in ICUs, and 70 were collected from general medicine/surgical floors. A total of 56 (23.1%) cultures yielded microbial growth. In phase II, there was a significant difference seen in positive cultures from PIVs and all other IV catheters (30.1% vs 18.7%; $P = .04$). A significant difference was also seen in the positivity of cultures obtained from general medicine/surgical floors compared with ICUs (32.9% vs 19.1%; $P = .03$).

There was a significant difference found in the rates of colonization of the catheters between phase I and phase II (41.9% vs 23.1%; $P < .0001$; Table 1). Multiple logistic regression was used and determined that this was statistically significant even after adjusting for location and line type ($P < .0001$). The logistic regression showed that the odds of having a positive culture in phase I with the split septum catheters was 2.60 times the odds of having a positive culture in phase II with the luer lock connecters and passive port protectors (95% confidence interval, 1.70, 3.98).

Of the positive cultures in phase I, 64 (65.3%) had <15 CFU, 17 (17.3%) had >15 CFU, and 17 (17%) had areas of confluent growth. Of those with confluent or >15 CFU, there was a similar distribution of growth by catheter type. Of the positive cultures in phase II, 37 (66.1%) had <15 CFU, 12 (21.4%) had >15 CFU, and 7 (12.5%) had confluent microbial growth. Based on visual plate inspection, the vast majority of positive cultures consisted of gram-positive organisms, primarily coagulase-negative staphylococci.

DISCUSSION

Needleless catheter connectors are widely used to prevent health care workers from bloodborne pathogen exposures. Although these devices have been shown to decrease both bloodborne pathogen exposure and injury, multiple needless catheter devices have also been associated with increased risk of bloodstream infections in both the hospital and the home health care setting.[6,14-17] To decrease risk of bloodstream infection, we previously evaluated the time necessary to adequately scrub a catheter connector diaphragm.[13] We also trialed a switch from a split septum catheter connector to a luer lock catheter connector, and experienced an increase in bloodstream infection.[9] Despite instituting further best practices, including new central venous catheter insertion checklists as well as chlorhexidine gluconate impregnated dressing, we continued to see elevated CLABSI rates.

We hypothesized that the split septum catheter connector might be associated with increased bacterial colonization because of its exposed system. After assessing the colonization rate at 41.9%, we believed this was unacceptably high and a decision was made institutionally to switch from the split septum catheter connector to the luer lock catheter connector with passive port protectors to decrease colonization and mitigate the potential increased difficulty in disinfection of the luer lock/mechanical connector. With this newly implemented system, we decided to assess colonization rates of the luer lock system to determine if the colonization rates were lower. To our knowledge, this is the first study to report colonization rates for both types of connectors, among several catheter types, during active patient care IV infusions, and demonstrates increased colonization risk with the open design of the split septum needless catheter connector as compared to the luer lock with passive port protector, with colonization rates of 41.9% and 23.1%, respectively.

In phase I with the split septum catheter connectors, there were no differences in colonization rates by catheter type or location, however, in phase II, there was a significant difference in the colonization of PIVs as compared with central catheters ($P = .04$) and in colonization on general medicine/surgery floors as compared with ICUs ($P = .03$). These findings may represent variances in nursing practices regarding catheter connector maintenance use and potential gaps regarding infectious risks of PIVs, as bloodstream infections from PIVs are infrequently recorded and tracked.[18,19]

The findings in this study are consistent with the limited literature regarding catheter connector colonization that have shown catheter connector colonization between 40% and 50%. In a prospective study by Holroyd et al,[20] split septum catheter connectors on central venous catheters in ICUs demonstrated 44% had some degree of bacterial growth, which is similar to the 38.8% that was found in phase I of our study, on specifically ICU patients. Of the 45 colonized connectors described by Holroyd et al,[20] 3 patients developed bacteremia, and in 2 of the 3 cases, the bacteria isolated from the connector and blood were concordant.[20,21]

Although the rates of bloodstream infections were not assessed in this study, a small number of bloodstream infections would be expected if we extrapolated the data from Holroyd et al.[20] The lower rate of colonization of the luer lock connector would then presumably result in a decreased likelihood of intraluminal spread of bacteria and subsequent bloodstream infection.

This is conceptually contrary to other studies in which the transition from split septum to a mechanical valve luer lock catheter connector has been associated with an increase in bloodstream infections.[9,14-17] However, the addition of a passive alcohol port protector was not used in these studies, and could possibly explain the variance that was seen in our data. Several additional factors could have led to the decrease in colonization including improvement in the technology of the enclosed system mechanical luer lock catheter connector compared with the previous models, increased adherence by nurses to catheter hub cleaning techniques, and the concurrent implementation of passive alcohol port protectors. Alcohol-based port protectors appear to be superior to conventional alcohol pledget swabs in reducing microbial transmission through luer lock needleless catheter

connectors.[22] Other quasi-experimental studies focused on CLABSI rates demonstrated decreases in CLABSIs by 34%-40% after introduction of passive alcohol port protectors.[23-25] Although passive alcohol port protectors may have played a role in reducing microbial colonization, given that the study was on active infusions that would not have port protectors in place, they may not be the primary cause of the decreased colonization rate.

Strengths of this study include the assessment of catheter connector colonization of 2 commonly used catheter connectors, from multiple catheter types, across multiple units of a tertiary care center, which is the first study to our knowledge to report such data. To our knowledge, this is the first study to assess catheter connector colonization in peripheral and central venous catheters in hospitalized patients during active infusions. The data collections were completed at the bedside and are therefore more representative of risk of colonization during clinical care as opposed to more controlled settings or laboratory trials.

This study has several limitations. There was no patient-specific data collected and outcomes, such as bloodstream infections, were not assessed; therefore, no correlation or causation can be inferred. As the study was not assessing any patient specific data, the duration of the catheter hubs was also not assessed. Although we sampled the connectors during active IV infusions, we did not record the infusate, and thus are unable to correlate colonization with specific IV fluids (total parental nutrition or lipid formulations). The study is also limited as alcohol port protectors were introduced simultaneously as the luer lock catheter connectors. Given the historic difficulty in cleaning catheter hubs, we believed this was warranted. These were only used, however, on catheters that were not active, and both phase I and phase II studies only assessed catheter connectors of active infusions. The selected catheter connectors were also a convenience sample and did not include all potential connectors, possibly biasing the result. However, the large number of connectors from different catheter types and units mitigates the risk of bias and confounding factors. The study did not assess how long each catheter was in place, so analysis regarding time-to-colonization based on catheter indwell was not feasible. Although we did not keep track of how long the catheter connectors were in place when cultured, per facility policy in concordance with manufacturer recommendations, IV tubing and catheter connectors were changed every 72-96 hours. Finally, this study was entirely performed at a single site, allowing for any specific nursing practices at the hospital or in a specific unit to impact the results.

CONCLUSIONS

Bacterial colonization of the lever lock split septum system was unacceptably high among all catheter types and hospital locations. This rate may be secondary to inappropriate scrubbing of catheter connectors or contamination of the connector during use. Although switching to a luer lock catheter connector with passive alcohol port protectors reduced colonization, the colonization rate remained high. Causation of colonization cannot be determined with these results. Given the potential risk of CLABSI, there is, however, a significant opportunity for further research to decrease colonization rates, and evaluate the correlation between catheter connector colonization and CLABSI.

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