

Summary of evidence on the effectiveness of the BD MaxPlus™ and BD MaxZero™ Needle-Free Connectors

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Table 1: Peer-reviewed publications evaluating the BD MaxPlus™ Needle-Free Connector design as part of a bundled best-practices approach for reducing central line-associated bloodstream infection (CLABSI) and associated costs

Study or published article title	First author, date and location of publication	Journal or conference of publication	Comparator	Methods	Comparator/ CLABSI rate	BD MaxPlus™ Needle-Free Connector/ CLABSI rate	Results	Conclusions/implications
Systematic Intervention to Reduce Central Line-Associated Bloodstream Infection Rates in a Pediatric Cardiac Intensive Care Unit[1]	John M. Costello, MD, 2008, Children's Hospital Boston, Harvard Medical School, Boston, MA	*Pediatrics,* the Official Journal of the American Academy of Pediatrics; 2008;121(5):915-923. DOI: 10.1542/peds. 2007-1577	Baxter™ Luer Activated Valve	This retrospective study aimed to establish a baseline CLABSI rate in a large, dedicated pediatric cardiac intensive care unit (CICU). Using an interrupted time-series design, we also sought to determine whether a multifaceted intervention would reduce the CLABSI rate. We converted our needleless connector to a device that has a flat access surface and contains a positive-displacement valve *(BD MaxPlus™ Needle-Free Connector).* The positive-displacement valve has a fully cleanable surface and eliminates retrograde flow into the catheter when an infusion device is disconnected from an infusion port.	Preintervention: 2,951/7.8 Partial intervention: 5,234/4.7	3,675 days; 2.3 CLABSI rate	The preintervention rate of 7.8 CLABSIs per 1,000 catheter days was significantly higher than the National Healthcare Safety Network (NHSN) benchmark. The full intervention rate of 2.3 CLABSIs per 1,000 catheter days was lower than the NHSN benchmark and trended toward statistical significance.	We think it is both practical and financially feasible to sustain this intervention over the long term. There were 15 fewer CLABSIs in the 9-month full intervention period, compared with the 9-month preintervention. Using published cost analyses from adult ICUs and general PICUs and assuming our initiative prevented ≈ 20 CLABSIs per year in our CICU, we estimate an annual attributable cost savings of $236,000–782,000.
Reduction of Central Line-Associated Bloodstream Infection Rates in Patients in the Adult Intensive Care Unit[2]	Mary C. Wallace, BSN, RN, CIC, 2016, University of Maryland-Baltimore Washington Medical Center, Glen Burnie, MD	*J Infus Nurs.* 2016;39(1):47-55. DOI:10.1097/NAN.000000000-0000151	A needle-free connector device difficult to disinfect adequately	The hospital's ICU used a focused-team approach to revise and improve central venous access device (CVAD) policies specific to nursing staff and physicians, which were updated to include the 2011 CDC guidelines and the INS Infusion Therapy Standards of Practice. CLABSI prevention initiatives also were undertaken and included CLABSI reporting, a bloodstream infection (BSI) alert system, bundle compliance monitoring and routine evaluation, and use of a positive displacement needle-free connector *(BD MaxPlus™ Needle-Free Connector clear, BD, San Diego, CA).*	CLD not available; 4.9	6,678; 0.6	In 2006, CLABSI rates reached a high of 4.8/1,000. The bundle compliance monitoring and routine evaluation activities resulted in decreased CLABSI rates of 2.8/1,000 central-line days in 2009 and 2.9/1,000 in 2010. After continuing the best practices and the implementation of the positive displacement needle-free connector, the CLABSI rates dropped and have remained statistically stable: 0.8/1,000 central line days *(95% CI [0.1, 3.0]) in 2011, 0 (95% CI [0.0, 1.8])* in 2012, and 0.91/1,000 *(95% CI [0.1, 3.3])* in 2013.	The use of needle-free connectors was an important factor that influenced the reduction in CLABSI rates observed in the hospital's ICU, the achievement of the target goal of zero by 2012 and the low CLABSI rate maintained in 2013. Microbial contamination of the catheter insertion site and/or access surface is the most likely source of catheter-related bloodstream infection (CRBSI). The use of positive displacement needle-free connectors has been shown to reduce both catheter access surface microbial contamination and infection rates. In one study, when a clear, swabbable, positive displacement needle-free connector and enhanced education on central venous access device (CVAD) care and maintenance were implemented, there was a significant and sustained reduction in CLABSI rates from 0.63 to 0 *($P < 0.05$).*

Table 1: Peer-reviewed publications evaluating the BD MaxPlus™ Needle-Free Connector design as part of a bundled best-practices approach for reducing CLABSI and associated costs *(cont'd)*

Study or published article title	First author, date and location of publication	Journal or conference of publication	Comparator	Methods	Comparator/ CLABSI rate	BD MaxPlus™ Needle-Free Connector/ CLABSI rate	Results	Conclusions/implications
Meta-analysis on Central Line-Associated Bloodstream Infections Associated with a Needleless Intravenous Connector with a New Engineering Design[3]	Ying P. Tabak PhD, 2016, San Diego, CA	*Am J Infect Control.* 2014;42(12):1278-1284.	Various	We reviewed MEDLINE, Cochrane Database of Systematic Reviews, Embase, ClinicalTrials.gov and studies presented in 2010–2012 at infection control and infectious diseases meetings. Studies reporting the CLABSIs in patients using the positive-displacement needle-free connector (NC) *(study NC)* compared with negative- or neutral-displacement NCs were analyzed. We estimated the relative risk of CLABSIs with the study NC for the pooled effect using the random effects method.	111,255; 1.5	95,383; 0.5	Our study revealed that the study NC, a new generation of NCs with improved patient safety design, was associated with reduced CLABSI risk.	Our meta-analysis demonstrated that the study NC with improved engineering design features that facilitate effective disinfections was associated with a lower risk of CLABSI. In the continuing evolution of the NCs, many have become complex in design. The complexities might have made some NCs harder to disinfect, flush completely or use correctly, all of which could contribute to CLABSI risk. In contrast, the design of the study NC has eight of the nine desired features outlined by infection prevention experts, including a solid, smooth external septum surface; a tight septum housing seal; a clear fluid pathway; minimal internal complexity; reduction or elimination of interstitial or dead space; elimination of a specific disinfection-clamping sequence; a straight fluid pathway; no blood reflux; and the ability to flush with saline alone. These desired features might explain, in part, the lower CLABSI rates seen in our meta-analysis.
Innovative Use of Existing Public and Private Data Sources for Postmarketing Surveillance of Central Line-Associated Bloodstream Infections Associated With Intravenous Needleless Connectors[4]	Ying P. Tabak PhD, 2014, San Diego, CA	*J Infus Nurs.* 2016;39(5): 328-335. doi: 10.1097/NAN.0000000000000185	All needle-free connectors used in hospitals in the United States who report CLABSI rates to CMS	The objective of this analysis was to evaluate the possibility of monitoring hospital-acquired CLABSI rates potentially associated with IV NC use by linking the publicly reported CMS hospital CLABSI data and IV NC use data from a private source, the study NC. CLABSI rates in hospitals using the study NC versus hospitals using other IV NCs were compared.	6,963,405 central line days; 7,847 CLABSI episodes; 1.13 CLABSI rate	2,923,859 of central line days; 3,017 CLABSI episodes; 1.03 CLABSI rate	The study NC hospitals had a lower unadjusted CLABSI rate *(1.03 per 1,000 central line days [3,017 CLABSIs/2,923,859 central line days])* compared with comparator hospitals *(1.13 per 1,000 central line days [7,847 CLABSIs/6,963,405 central line days], P < 0.0001).* The NHSN CLABSI standardized infection ration (SIR) was 0.51 *(95% confidence interval [CI]: 0.49, 0.53)* for the study NC hospitals versus 0.57 *(95% CI: 0.56, 0.58)* for comparator hospitals.	The CMS data are current, comprehensive and representative of all U.S. acute care hospitals in bed size, teaching status, rural status and geographic locations. Effort may be expanded to encourage industry to participate in the FDA initiatives by providing the FDA access to hospital-level device use data. This government and private-sector partnership may enable the FDA to electronically monitor nationwide device safety signals with a practical and minimum burden approach. This analysis demonstrated that the study device was not associated with elevated CLABSI, as it demonstrated statistical noninferiority.

Table 1: Peer-reviewed publications evaluating the BD MaxPlus™ Needle-Free Connector design as part of a bundled best-practices approach for reducing CLABSI and associated costs *(cont'd)*

Study or published article title	First author, date and location of publication	Journal or conference of publication	Comparator	Methods	Comparator/ CLABSI rate	BD MaxPlus™ Needle-Free Connector/ CLABSI rate	Results	Conclusions/implications
Impact of Needleless Connector Change Frequency on Central Line-Associated Bloodstream Infection Rate[5]	Thomas J. Sandora MD, MPH, August 2010 to January 2012, Boston Children's Hospital, Harvard Medical School, Boston, MA	*Am J Infect Control.* 2014;42(5):485-489. http://dx.doi.org/10.1016/j.ajic.2014.01.022	This study compared line change frequency.	To assess the association between NC change frequency and CLABSI rate, we modeled monthly pediatric stem cell transplant (SCT) CLABSI rate in 3 periods: baseline period during which NC were changed every 96 hours regardless of infusate *(period 1);* trial period in which NC were changed every 24 hours with blood or lipid infusions *(period 2);* and a return to NC change every 96 hours regardless of infusate *(period 3).*	0.41 for first period, 0.3 for third period; changing every 96 hours	3.56 for second period; changing every 24 hours with blood or lipids	SCT CLABSI rates were 0.41, 3.56 and 0.03 per 1,000 central line days in periods 1, 2 and 3, respectively. In multivariable analysis, the CLABSI rate was significantly higher in period 2 compared with both period 1 *(P ¼ .01)* and period 3 *(P ¼ .003).* In contrast, CLABSI rates on the oncology unit were not significantly different among periods.	In this quasi-experimental study, we found that changing NC every 24 hours when blood products or lipids are infused was associated with significantly higher CLABSI rates in hospitalized pediatric SCT patients. Although central line insertion practices are an important part of CLABSI prevention, evidence suggests that daily line maintenance care contributes more strongly to CLABSI risk among hospitalized children. Until additional research is available, we believe that national recommendations regarding NC change frequency should be revisited and clarified. Pediatric SCT units that have been unable to reduce CLABSI rates using standard infection prevention strategies should consider a trial of changing NC less frequently than every 24 hours when blood products or lipids are being infused.
Implementing a Better Bundle to Achieve and Sustain a Zero Central Line-Associated Bloodstream Infection Rate[6]	Timothy Royer, BSN, RN, CRNI®, 2010, VA Puget Sound Health Care System, Seattle, WA	*J Infus Nurs.* 2010;33(6):398-406. doi: 10.1097/NAN.0b013e3181f8586b	BD SmartSite™ Plus Needle-Free Connector, BD, San Diego, CA	To prevent morbidity, mortality and excess cost of care, it is the objective of every healthcare facility to achieve and maintain a 0 CLABSI rate. To achieve this goal, 6 years of prospective surveillance and enhanced central line care that included the implementation of several interventions beyond the generally accepted central line bundle (CLB) was accomplished through a dedicated, nurse-driven vascular access team.	Central line days unavailable; 1.73	Sustained 0 for 17 months	In January 2007, when the clear swabbable needle-free connector and enhanced education on central line care and maintenance were implemented, there was a significant reduction in CLABSI rates from 0.63 to 0, a 100% decrease. The 0 infection rate has been maintained for over 17 months.	The flat, swabbable access surface of the needle-free connector implemented in this surveillance was associated with a reduction in contaminated blood cultures as well as a reduction in the CLABSI rate. Needle-free connectors should be evaluated individually as to the presence or absence of the risk factors associated with an increased risk of CLABSI. The use of a clear, swabbable, positive displacement needle-free connector contributed to a significant decrease in CLABSIs. As of July 2009, there have been 17 months without a CLABSI in the hospital.

Table 2: Poster presentations evaluating the BD MaxPlus™ Needle-Free Connector design as part of a bundled best practices approach for reducing CLABSI

Study or published article title	First author, date and location of publication	Journal or conference of publication	Comparator	Methods	Comparator data	BD MaxPlus™ Needle-Free Connector data	Results	Conclusions/implications
Peripherally Inserted Central Catheter (PICC) Occlusion Reduction in an Adult Population with a the Use of a Positive Displacement Needleless Connector[7]	Lori Hull-Grommesh, DNP, APRN, ACNP-BC, CCRN, 2011, Memorial Hermann, Houston, TX	2011 Association for Vascular Access Conference	InVision® Connector	Over a 13-month period, data was collected regarding peripherally inserted central catheter (PICC) line occlusions. The analysis of the data revealed a PICC line occlusion rate of up to 55% per month with an average occlusion rate of 33% per month. A neutral fluid cap was in use during the data collection. The positive fluid displacement cap was subsequently trialed for a 1-month period.	55% occlusion rate	7% occlusion rate	The initial 1-month trial period with the positive displacement cap vs the neutral or zero displacement cap resulted in an occlusion rate of 4.1%. To verify these results the positive pressure displacement cap was again trialed for 2 months. The average PICC occlusion rate for the 3-month period was 6.3%.	There was a 0 CLABSI rate during the trial period. The CLABSI rate has remained at 0 for PICC catheters.
Beyond the Bundles for Reducing Central Line-Associated Bloodstream Infections: Additional Measures Used to Reach the Zero Target[8]	Jennifer McCord, MSN, RN, PCCN, CCRN, CCNS, VA-BC, 2011, Bethesda North Hospital, Cincinnati, OH	2011 Society for Healthcare Epidemiology of America Conference	Three different connectors in a three hospital system institution	Our institution formed a community wide initiative. Recommendations from government agencies were implemented, including the recognized insertion bundle. November 2008: Removed three end caps from our facilities; MaxPlus clear implemented.	CLABSI rate = 1.314; line occlusions = 15.6%	CLABSI rate = .382; line occlusions = 4.56%	Between January 2008 and December 2010, we saw a 71.7% reduction in line occlusions and a 58% reduction in alteplase use. CLABSI rates decreased from 1.314 infections per 1,000 catheter days to 0.382 per 1,000 catheter days, representing an 71% decrease.	Total cost savings in 2009 and 2010 through the intervention of changing from three end caps to positive displacement is as follows: Alteplase reduction savings of $191,648 and CLABSI reduction savings of $315,000–450,000, for a 2-year savings of $506,648–641,648.
Comparison of Catheter Occlusions Between a Mechanical Valve Injection Cap and Positive Displacement Injection Cap[9]	Debbie Cain, RN, CRNI, 2010, Springfield, MO	National Home Infusion Association Conference 2010	Clave® Needle-Free Connector	A retrospective study of all VADs requiring declotting agent over a 1-year period was performed. The organization also evaluated the number of CRBSI during the time frame of the mechanical valve (MV) use and after implementation of a positive pressure mechanical valve (PPMV).	November 2008 to May 2009, 0.18% CRBSI rate	June 2009 to March 2010, 0.04% CRBSI rate	The organization recognized a significant decrease in CRBSI with implementation of the PPMV. The organization evaluated risk vs benefit with the MV and PPMV and will continue to utilize the PPMV.	The occlusion rate since January 2010 is 0.36 per 1,000 catheter days, a 66% decrease over the MV period. The CRBSI rate also continues to decline. As of March 2010, the CRBSI rate is 0.04 per 1,000 catheter days, a 78% decrease from the MV period.
In Search of Zero: Eight Years of Interventions Lead to Reduced CLABSI Rates[10]	Lee Steininger, RN, CIC, 2010, Kindred Hospital—Tucson, Tucson, AZ	The Society of Healthcare Epidemiology of America Conference, 2010	MicroClave® Clear Neutral Displacement Connector	This study was conducted as a prospective observational time series study. In 2000, the CLABSI rate at this long-term acute care hospital (LTACH) was higher than the national benchmark. To reduce the CLABSI rate, several interventions were implemented at various time intervals and CLABSI rates were collected. Prospective BSI surveillance and case finding was the responsibility of the infection preventionist.	April 2008, CLABSI rate = 1.5	May to December 2008, CLABSI rate = 1.18	Infection rates were tracked monthly using the NHSN definitions. April 2008: Clear cap chosen to replace previous neutral pressure caps after 68% savings on use of alteplase was realized because lines were not clotting off as with the neutral pressure cap previously used. February to June 2009 represented 120 days without a CLABSI.	Most devices will initially lead to short-term results. The value of any intervention to an effective CLABSI reduction program is a sustainable positive result. With the clear, positive displacement swabbable connector in place for 16 months the results have proven to be sustainable. As of the end of July 2009, the CLABSI rate at this facility was 0.98 per 1,000 central line days.

Table 3: Poster presentations evaluating the effect of the BD MaxPlus™ Needle-Free Connector design on central venous catheter (CVC) thrombotic catheter occlusion and associated costs

Study or published article title	First author, date and location of publication	Journal or conference of publication	Comparator	Methods	Comparator data	BD MaxPlus™ Needle-Free Connector data	Results	Conclusions/implications
Peripherally Inserted Central Catheter (PICC) Occlusion Reduction in an Adult Population with the Use of a Positive Displacement Needleless Connector[7]	Lori Hull-Grommesh, DNP, APRN, ACNP-BC, CCRN, 2011, Memorial Hermann, Houston, TX	2011 Association for Vascular Access Conference	InVision® Connector	Over a 13-month period, data was collected regarding PICC line occlusions. An occlusion was defined as inability to flush and/or lack of blood aspiration of any or all lumens. The analysis of the data revealed a PICC line occlusion rate of up to 55% per month with an average occlusion rate of 33% per month. There was no correlation unit location or patient diagnoses. A neutral fluid cap was in use during the data collection.	55% occlusion rate	7% occlusion rate	The initial 1-month trial period with the positive displacement cap vs the neutral or zero displacement cap resulted in an occlusion rate of 4.1%. To verify these results the positive pressure displacement cap was again trialed for 2 months. The average PICC occlusion rate for the 3-month period was 6.3%.	The use of a positive displacement cap resulted in a reduction of PICC line occlusions to 7%, from 33%, a 79% reduction. Total lines were 226 in a 90-day trial with 16 occlusions. Hospital savings on 90-day study: $5,207.04. Projected annual hospital savings: $17,760. Alteplase savings from 90-day study: $4,640. Projected annual alteplase savings: $33,200. There was a 0 CLABSI rate during the trial period. The CLABSI rate has remained at 0 for PICC catheters.
Beyond the Bundles for Reducing Central Line-Associated Bloodstream Infections[8]	Jennifer McCord, MSN, RN, PCCN, CCRN, CCNS, VA-BC, 2011, Bethesda North Hospital, Cincinnati, OH	2011 Society for Healthcare Epidemiology of America Conference	Three different connectors in a 3-hospital system institution	Our institution formed a community-wide initiative. Recommendations from government agencies were implemented, including the recognized insertion bundle. November 2008: removed three end caps from our facilities; BD MaxPlus™ Needle-Free Connector clear implemented.	CLABSI rate = 1.314; line occlusions = 15.6%	CLABSI rate = 0.382; line occlusions = 4.56%	Between January 2008 and December 2010, we saw a 71.7% reduction in line occlusions and a 58% reduction in alteplase use. CLABSI rates decreased from 1.314 infections per 1,000 catheter days to 0.382 per 1,000 catheter days, representing an 71% decrease.	Total cost savings in 2009 and 2010 through the intervention of changing from three end caps to positive displacement is as follows: Alteplase reduction savings of $191,648 and CLABSI reduction savings of $315,000–450,000, for a 2-year savings of $506,648 –641,648.
Comparison of Catheter Occlusions Between a Mechanical Valve Injection Cap and Positive Displacement Injection Cap[9]	Debbie Cain, RN, CRNI, 2010, Springfield, MO	National Home Infusion Association Conference 2010	Clave® Needle-Free Connector	A retrospective study of all VADs requiring declotting agent over a 1-year period was performed. The organization also evaluated the number of CRBSIs during the time frame of the MV use and after implementation of a PPMV.	November 2008 to May 2009, 1.06% occlusion rate, 0.18% CRBSI rate	June to December 2009, 1.59% occlusion rate, after clinical education; January to March 2010, 0.36% occlusion rate, June 2009 to March 2010	The organization evaluated risk vs benefit with the MV and PPMV and will continue to utilize the PPMV. After several clinical practice changes are implemented further studies will be conducted to evaluate if the increase in clotted VADs is related to the PPMV vs clinical practice.	In January 2010, further education was completed, including: prime injection cap inverted; eliminate air from injection cap; flush unused lumen if aspirating blood; flush catheter after episodes of emesis. These clinical practice changes are associated with a significant decrease in the occlusion rate. The occlusion rate since January 2010 is 0.36 per 1,000 catheter days, a 66% decrease over the MV period. The CRBSI rate also continues to decline. As of March 2010, the CRBSI rate is 0.04 per 1,000 catheter days, a 78% decrease from the MV period.

Table 3: Poster presentations evaluating the effect of the BD MaxPlus™ Needle-Free Connector design on CVC thrombotic catheter occlusion and associated costs *(cont'd)*

Study or published article title	First author, date and location of publication	Journal or conference of publication	Comparator	Methods	Comparator data	BD MaxPlus™ Needle-Free Connector data	Results	Conclusions/implications
In Search of Zero: Eight Years of Interventions Lead to Reduced CLABSI Rates[10]	Lee Steininger, RN, CIC, 2010, Kindred Hospital—Tucson, Tucson, AZ	The Society of Healthcare Epidemiology of America Conference, 2010	MicroClave® Clear Neutral Displacement Connector	This study was conducted as a prospective observational time series study. In 2000, the CLABSI rate at this LTACH was higher than the national benchmark. To reduce the CLABSI rate, several interventions were implemented at various time intervals and CLABSI rates were collected. Prospective BSI surveillance and case finding was the responsibility of the infection preventionist.	April 2008, CLABSI rate = 1.5	May to December 2008, CLABSI rate = 1.18	Infection rates were tracked monthly using the NHSN definitions. April 2008: clear cap chosen to replace previous neutral pressure caps after 68% savings on use of alteplase realized because lines were not clotting off as with the neutral pressure cap previously used. February to June 2009 represented 120 days without a CLABSI.	Most devices will initially lead to short-term results. The value of any intervention to an effective CLABSI reduction program is a sustainable positive result. With the clear, positive displacement swabbable connector in place for 16 months the results have proven to be sustainable. As of the end of July 2009, the CLABSI rate at this facility was 0.98 per 1,000 central line days.
Central Line Occlusion Complications Utilizing Varying Connectors[11]	Chuck Ramirez, 2011, Banner Estrella Medical Center, AZ	Association of Vascular Access Conference, 2011	MicroClave® Clear Neutral Displacement Connector	The connector trial was designed to look at all central lines, including PICC lines, for any complications associated with occlusion or reduced flushing. A database of line complications was maintained by a central line team. A pharmacy team pulled together retrospective and current Cathflo® Activase usage during the pilot. Clamping was not utilized on any central line. Data was first collected on existing cap CLC 2000 as a benchmark for occlusion complications. Then a 30-day trial was conducted utilizing the MicroClave® Clear Neutral Displacement Connector and BD MaxPlus™ Needle-Free Connector, respectively.	17/31	10/0	MicroClave® Clear Neutral Displacement Connector number of documented complications = 17; 1 catheter replacement. Cathflo® Activase usage = 31. BD MaxPlus™ Needle-Free Connector number of documented complications = 10. No catheter replacements. Cathflo® Activase usage = 20.	Having utilized the central line bundle for many years, focus has shifted to maintenance-related complications. Various connector configurations are now available with the focus being on the cap surface and lower colonization. However, the trial did identify that in moving toward the newer lower colonization connectors, we may have unintended consequences.
Luer Activated Device (LAD) Performance: Comparing Positive Pressure, Neutral and Negative Pressure Devices Clinically and with Laboratory Follow Up Testing[12]	Andre Schotte, RN, PhD, 2008, Riverside Regional Medical Center, CA	Infusion Nurses Society, 2008, First Place Clinical Research Poster	MicroClave® Clear Neutral Displacement Connector	Although multiple factors predispose CVADs to occlusion, reflux of blood during medication or flush syringe disconnect is often implicated. Over a 7-week period, occlusion data was collected on 28 in-house ICU and medical surgery patients with the dual lumen PowerPICC. A positive pressure MaxPlus LAD was placed on one lumen and a blue neutral pressure LAD was placed on the other lumen.	Withdrawal occlusion = 11; total occlusion = 9	Withdrawal occlusion = 1; total occlusion = 0	These differences were similar to those found by Schilling et al, where negative pressure LADs were compared to positive pressure LADs. These results led to a question about neutral valve performance and the meaning of *neutral.* As a follow up to this clinical study, positive, negative and neutral pressure valves were tested in the laboratory to understand their performance differences when attached to a PICC catheter.	With the exception of the positive pressure LADs, all needleless devices demonstrated negative reflux upon syringe disconnect. Further, even though neutral pressure LADs may have reduced negative pressure, our clinical results indicate that this reduction is not sufficient to prevent increased iuncidences of intraluminal clot formation. It should be noted that blood reflux during the connection with a syringe did not increase the risk of occlusion in our clinical results. Reflux during disconnect was the correlating factor. Hospitals need to be aware of a possible association between new LADs and an increase in occlusions and infections.

Table 4: Peer-reviewed publications evaluating the BD MaxPlus™ Needle-Free Connector design and disinfection effectiveness

Study or published article title	First author, date and location of publication	Journal or conference of publication	Comparator	Methods	Comparator data	BD MaxPlus™ Needle-Free Connector data	Results	Conclusions/implications
Microbiologic Contamination of a Positive- and a Neutral Displacement Needle-Free Intravenous Access Device in Clinical Use[13]	A.L. Casey PhD, 2016, University Hospitals Birmingham National Health Service Foundation Trust, The Queen Elizabeth Hospital, Birmingham, Edgbaston, Birmingham, UK	*Am J Infect Control.* 2016;44(12):1678-1680. doi: 10.1016/j.ajic.2016.06.027.	MicroClave® Clear Neutral Displacement Connector	An opaque neutral-displacement device was routinely used on patients' central venous catheter (CVC) on the hematoma-oncology ward at the University Hospitals NHS Foundation Trust. The microbial contamination rate of this device was investigated for 3 months. Healthcare workers were then trained to use a transparent positive displacement device *(BD MaxPlus™ Needle-Free Connector clear).* Microbial contamination was subsequently investigated for 6 months. The neutral-displacement device was then implemented, and microbial contamination was studied for 3 months.	Devices with a contaminated septum: 79 out of 276. Devices with contaminated internal fluid path: 11 out of 276. Patients with ≥1 device with contaminated internal fluid path: 6 out of 78.	Devices with a contaminated septum: 118 out of 281. Devices with contaminated internal fluid path: 37 out of 281. Patients with ≥1 device with contaminated internal fluid path: 31 out of 84.	The use of a positive-displacement needleless intravenous access device was associated with lower microbial contamination rates compared with a neutral-displacement device when used on central venous catheters in hematoma-oncology patients.	In a previous laboratory study, the positive-displacement device used during the study was associated with lower rates of microbial ingress. These results were supported by the current study, whereby the rate of internal fluid pathway contamination was lower in the positive-displacement group despite being *in situ* for longer. These lower contamination rates may be related to the topography of the septa, which influences decontamination efficacy. This is supported by microbial contamination of the septa also being lower in this group. However, findings from this study and previous publications on this positive-displacement device suggest that the infection risk associated with needle-free IV access devices is device-specific and not class-specific.
An In Vitro Comparison of Microbial Ingress Into 8 Different Needle-Free IV Access Devices[14]	Anna Casey, PhD, BSc, 2015, University Hospitals Birmingham NHS Foundation Trust, Birmingham, UK	*J Infus Nurs.* 2015;38(1):18-25. doi: 10.1097/NAN.0000000000000082	Seven different needle-free IV access devices	This work was carried out by a National Health Service (NHS)-employed clinical research scientist in a containment level 2 laboratory. The objective of the current study was to ascertain whether different needle-free IV access devices, including positive-displacement valves, provide a similar physical barrier to prevent the ingress of microorganisms when microbiologically challenged under simulated controlled clinical conditions. The devices were subjected to 7 days of clinical simulation.	Following 7 days of use with a 5 second scrub, significantly fewer microorganisms were detected in the eluates collected from the MaxGuard™ Needleless Connector and BD MaxPlus™ Needle-Free Connector clear compared with the Bionector® Needleless Connector, MicroClave® Clear Neutral Displacement Connector, and V-Link™ Luer-Activated Device. In addition, fewer microorganisms were detected in the eluates collected from the BD MaxPlus™ Needle-Free Connector than the MicroClave® Clear Neutral Displacement Connector.		The positive displacement mechanical valves—CareSite ® Luer Access Device, MaxGuard™ Needleless Connector, and BD MaxPlus™ Needle-Free Connector— were associated with ingress of significantly fewer microorganisms compared with several of the other devices tested. This may have been related to the design and, in particular, to the topography of the injection sites of these devices, which in turn may have influenced the efficacy of the decontamination process. The positive displacement devices were correspondingly associated with significantly fewer contaminated administration set male users than the other devices tested, which supports the conjecture that the injection site designs may be easier to decontaminate. Interestingly, despite decontamination of the needle-free IV access devices before attachment of administration sets, more than half of all the male luers were contaminated with *S. aureus* following insertion into the devices. This again may reflect microbial contamination of elements of the needle-free IV access devices, which are not easily decontaminated. Significantly fewer CFU were recovered from needle-free IV access devices with relatively large priming volumes, such as the BD MaxPlus™ Needle-Free Connector, than those with small priming volumes, including the Bionector® Needleless Connector.	

Table 5: Peer-reviewed published studies evaluating the effect of the BD MaxZero™ Needle-Free Connector design on CVC thrombotic catheter occlusion

Study or published article title	First author, date and location of publication	Journal or conference of publication	Comparator	Methods	Comparator data	BD MaxPlus™ Needle-Free Connector data	Results	Conclusions/implications
Catheter Occlusion in Home Infusion: The Influence of Needleless Connector Design on Central Catheter Occlusion[15]	Ann Williams RN, CRNI Infusion Specialist, Deaconess Home Services	*J Infus Nurs.* 2018;41(1):52-57. doi: 10.1097/NAN.0000000000000259	MicroClave® Clear Neutral Displacement Connector	This is a retrospective observational study conducted by Deaconess Home Care to assess the impact of needleless connector design on the CVC occlusion rate. Data were analyzed from patients with medical or surgical conditions who received home infusion therapy through a CVC between May 2014 and June 2016. Split-septum neutral-displacement connectors *(MicroClave® Clear Neutral Displacement Connector; ICU Medical, San Clemente, CA)* were used from May 2014 to July 2015, and solid-surface neutral-reflux connectors *(BD MaxZero Needle-Free Connector; BD Medical, Franklin Lakes, NJ)* were used from August 2015 to June 2016.	77 doses of alteplase; 58 nurse visits during the MicroClave® Clear Neutral Displacement Connector needle-free connector period	40 doses of alteplase; 28 nurse visits during the MaxZero™ Needle-Free Connector period	Overall, after switching from a split-septum neutral-displacement needle-free connector to a solid-surface neutral-reflux needleless connector, there was a 55.6% reduction in the total number of doses of alteplase per 100 central-line days and a 56.4% reduction in the associated cost. There was a 42.9% reduction in the total number of nurse visits per 100 central line-days and a 55.1% reduction in the associated cost after patients were switched to the solid-surface neutral-reflux needle-free connectors.	Eight months following conversion to MaxZero™ Needle-Free Connectors, we observed the following: a reduction in thrombotic CVC occlusions improved work flow process by decreasing nursing visits to assess and resolve complications. At an average price of $110 per dose of Cathflo® Activase and $100 per nursing visit, we conservatively estimate an annualized cost saving of $21,405 as the result of converting to BD MaxZero™ Connectors. Using BD MaxZero™ Connectors resulted in improved clinical and financial outcomes. Well-designed clinical studies evaluating the performance and comparative risk-benefit analyses of various needleless connectors are needed to guide evidenced-based decision-making. The results of the current study suggest benefits of a neutral-reflux needleless connector in reducing occlusion rate and associated costs.

Table 6: Poster presentations evaluating the effect of the BD MaxZero™ Needle-Free Connector design on CVC thrombotic catheter occlusion

Study or published article title	First author, date and location of publication	Journal or conference of publication	Comparator	Methods	Comparator data	BD MaxPlus™ Needle-Free Connector data	Results	Conclusions/implications
Decreasing the Incidence of Fibrin Sheaths in the BMT Unit by Changing to a Positive Displacement Needle-Free Connector[16]	Misty Lamprecht, 2017, Ohio State University Wexner Medical Center-James Cancer Hospital	BMT Tandem Meeting, 2017	Neutral needle-free connector	The BMT unit began to experience fibrin sheaths in CVCs when a new injection cap was implemented. This led to our attempt to correct the problem. Baseline data was collected for 10 days, Each CVC blood draw was recorded and an incident rate was calculated. Baseline data showed a 15% incidence of sheath presence. The product used by the other institutions was trialed. The process began with a 10-day implementation that consisted of conversion to the trial product. After the implementation period, data collection occurred for 10 days.	Initial neutral connector: 15% fibrin sheath formation; second neutral connector trialed 13% fibrin sheath formation; third neutral connector trialed 5% fibrin sheath formation	BD MaxZero™ Needle-Free Connector fibrin sheath formation 3%	Three products were trialed with the same procedure. The products showed a sheath incidence of 13%, 5% and 3%. Based on these findings and a staff review of all products, a recommendation has been put forth to the value analysis team (VAT) to implement a change to the BMT unit and a trial of the product in other areas for potential conversion of the entire hospital.	Having strong evidence to support this recommendation will influence the VAT to support the purchase of the new product. It will also elicit nursing support for the implementation of this product as an evidence-based practice change.
The Use of Positive Displacement IV Connectors Contributes to the Prevention of Central Venous Access Device (CVAD) Occlusion[17]	Nicola York, Clinical Nurse Manager Vascular Access Department, Oxford University Hospitals Trust	NHS Trust Oxford University Hospitals 2013	Negative displacement connector	A retrospective review of the CVAD occlusion rates over a 24-month period was carried out. Data from the first 12-month period prior to the introduction of a positive displacement IV connector was compared with data from the 12-month period following the introduction of the positive displacement IV connector.	January–December 2011, 1,250 CVADs were inserted. A total of 17 *(1.36%)* catheter occlusions were recorded.	January–December 2012, 1,168 CVADs were inserted. A total of three *(0.25%)* catheter occlusions were recorded.		As shown from the results, there is a downward trend confirming a reduction in the number of CVAD occlusions. This reduction in CVAD occlusions, however, cannot be exclusively attributed to the use of the positive pressure IV connectors as other measures were also implemented at the same time: namely, an increase in training and education for staff managing CVAD.

Table 7: Published studies discussing positive displacement needle-free connectors

Study or published article title	First author, date and location of publication	Journal or conference of publication	Results	Conclusions/implications
Outbreak Column 19: Needleless Connectors (NCs) Tales from Nine Outbreaks[18]	Evonne Curran, 2016; Health Protection Scotland, Glasgow, UK	*J Infect Prev.* 2016;17(5):241-247. doi:	A critical review of historical outbreak reports that are still influencing practice today is presented. These outbreak reports were used as evidence in support of guideline recommendations and of the U.S. Food and Drug Administration's (FDA) advisory notice requiring postproduct surveillance for NC which have a positive displacement. Some nonrandomized uncontrolled studies make vast claims or hint at problems, which can be persuasive to NC purchasing decision-makers. For example, researchers claimed that a change from positive or negative NCs to a zero displacement NC saved over $3 million and 13 lives *(Chernecky et al., 2014).* The study involving six centers and a cumulative 140 study months provided a results section of one paragraph and one small table. *(At the time of writing this paper, the article by Chernecky et al. [2014], of which Jarvis is also a coauthor, was retracted. The retraction notice stated that the science was flawed.)* Errors are generally brought about by a system inclusive of resource/workload mismatch, procedure complexity and cognitive errors. There is no suggestion that people set out to deceive here, but obvious errors and omissions happened. The findings of opinions considered as evidence, unsubstantiated claims, incompleteness in reporting and unexplored outbreak-provoking explanations all led to—and continue to present—unwarranted alarm against some NCs.	The conclusions are that the evidence, as reported, does not support there being an increased risk from positive displacement NCs. Identified in this review were unsubstantiated claims, incompleteness in reporting of specifics, opinions considered as evidence and unexplored outbreak-provoking explanations.

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