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REDUCING CENTRAL LINE-ASSOCIATED BLOODSTREAM INFECTIONS AT A RURAL MIDWESTERN HOSPITAL THROUGH AN EVIDENCE-BASED NURSE-LED PRACTICE CHANGE INTERVENTION

Crystal B. LaValley
Northern Michigan University, crlavall@nmu.edu

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By

Crystal B. LaValley

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Committee Chair: Date

PhD, FNP-BC 4/20/22

First Reader: Date

DNP, MPA CRNA FNP-C 4/27/22

Second Reader (optional): Date

RN PhD April 15th 2022

Department Head: Date

ABSTRACT

REDUCING CENTRAL LINE-ASSOCIATED BLOODSTREAM INFECTIONS AT A RURAL MIDWESTERN HOSPITAL THROUGH AN EVIDENCE-BASED NURSE-LED PRACTICE CHANGE INTERVENTION

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Central line-associated bloodstream infections (CLABSIs) are responsible for increased patient morbidity, mortality, and healthcare costs, despite being a preventable harm (Barnes et al., 2015; Furuya et al., 2016). Evidence-based (EB) research suggests that the use of central line bundles is the most effective way to reduce CLABSIs in hospitals (Barnes et al., 2015; Furuya et al., 2016). Researchers have also found a statistically significant correlation between nurse compliance with bundle components and CLABSI rates (Aloush & Alsaraireh, 2018; Furuya et al., 2016). The purpose of this study was to determine if a nurse-led collaborative that focused on CLABSI reduction using EB prevention strategies, with an emphasis on maintenance bundles, in the form of a Central Line Adult Point Prevalence Tool (CLAPPT), was successful in decreasing CLABSIs at a rural Midwestern hospital. Nurse compliance with the CLAPPT following formal education was also explored. A retrospective analysis of CLABSI rates pre- and post-intervention and nurse compliance was performed. The results of this study showed CLABSI rates and number of catheter days increased, despite an improvement in nurse compliance with the interventions. The global pandemic of 2020 caused the focus of U.S. hospitals to shift from best hospital acquired infection (HAI) control practices to COVID-19 mitigation, which led to an uptick in HAIs nationwide (Centers for Disease Control and Prevention, n.d.-d). Unfortunately, this healthcare facility was no exception.

DEDICATION

This This Doctor of Nursing Practice project is dedicated to those who have supported, encouraged, and believed in me every step of the way. Thank you to Paula and John Huff for opening your doors to me all those years ago and supporting and encouraging me in the early days of my college career. Your kindness and generosity will not be forgotten. Thank you to my uncle James Koesling, who gave up many Saturday mornings to tutor me in math, physics, and hydraulic calculations so that I could acquire my first undergraduate degree in Fire Protection Engineering. Although I changed careers, the many hours spent at your kitchen table helped shape who I am today and prepared me for the many collegiate challenges that lay ahead. Thank you to my parents for your constant show of love and support. Finally, and most importantly, thank you to my husband, Matthew LaValley, for being my safe place and my solid ground throughout my educational journey, I love you more than life itself.

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Chapter One

Background and Significance

Healthcare associated infections (HAIs), also known as nosocomial infections, are acquired throughout the course of medical treatment at a healthcare facility and are not present or in incubation upon admission (World Health Organization, 2020). They can be further defined as infections occurring within 48 hours of admission or within 14 days of hospital discharge (Cardoso et al., 2014). HAIs pose a global health threat, affecting hundreds of millions of patients annually (The Joint Commission, 2022a). In the United States, they are the number one adverse event in healthcare and the fifth leading cause of death in acute care settings (Septimus & Moody, 2016). Approximately 15% of those hospitalized will develop a HAI, accounting for an estimated 1.7 million infections and 99,000 deaths per year (Septimus & Moody, 2016).

Modern advancements in healthcare have led to the routine use of invasive medical procedures and/or devices to treat patients. HAIs can result from the utilization of these devices, such as catheters and ventilators, during procedures, or they may develop at the procedural site. Reportable HAIs that are currently tracked through national surveillance networks include central line-associated bloodstream infections (CLABSIs), catheter-associated urinary tract infections (CAUTIs), surgical site infections (SSIs), ventilator associated pneumonia (VAP), and hospital-onset *C. difficile* and methicillin-resistant *Staphylococcus aureus* (MRSA) bacteremia (Centers for Disease Control and Prevention, n.d.-f). Combined, these infections cost the U.S. healthcare system an estimated $9.8 billion per year (Septimus & Moody, 2016). Federal agencies, such as the Centers for Disease Control and Prevention (CDC), the Centers for Medicare and Medicaid Services (CMS), and the Department of Health and Human Services (HHS), recognize HAIs as a priority patient safety concern. In turn, they have bolstered their HAI prevention efforts (Centers for Disease Control and Prevention, n.d.-g; Office of Infectious Disease and HIV/AIDS Policy, n.d.; U.S. Centers for Medicare & Medicaid Services, 2020). Furthermore, the largest accrediting body in healthcare, The Joint Commission (TJC), identifies HAI prevention as one of their National Patient Safety Goals (The Joint Commission, 2022b).

Despite their significance, the true incidence and financial burden of HAIs has yet to be fully elucidated. Inconsistencies in HAI definitions and reporting requirements at the federal, state, and local levels have historically created challenges in the accurate measurement of the total impact of HAIs (Herzig, Reagan, Pogorzelska-Maziarz, Srinath, & Stone, 2015). In 1999, a call to action was published by the Institute of Medicine (IOM) with the groundbreaking report "To Err is Human" (Barnes et al., 2015; Havens & Boroughs, 2000). This prompted governments to begin working toward increasing patient safety, including HAI reduction. State governments began enacting policies for mandatory reporting in 2003 (Barnes et al., 2015). Since then, 37 of 50 U.S. states and territories have enacted these mandates and research suggests that all 50 states participate in some type of HAI prevention effort (Herzig et al., 2015).

The federal sector has yet to regulate state participation in public reporting; however, in 2005 they established reporting requirements through CMS, which laid the foundation for the expansion of federal efforts in HAI prevention (Barnes et al., 2015). CMS Quality Reporting Programs (QRPs) were developed in 2011 as the result of the Patient Protection and Affordable Care Act of 2010 (ACA) quality improvement directives, which also focused on HAI prevention. This required the majority of healthcare facilities to report certain HAI data for participation in CMS QRPs and directly tied CMS reimbursements to hospitals' HAI performance data (Leach, 2020; National Center for Emerging and Zoonotic Infectious Diseases, Division of Healthcare Quality Promotion, n.d.-b). Prior to 2011 HAI tracking and reporting was left to the discretion of individual healthcare facilities (Leach, 2020). Therefore, each facility could have been tracking different HAIs with foci on varying populations of interest. In 2011, federally regulated healthcare facility HAI reporting requirements were established through CMS and initiated by requiring tracking of CLABSIs in adult, pediatric, and neonatal intensive care units (ICUs). These regulations evolved over the next few years to include CAUTI, MRSA, *C. difficile*, and SSIs, along with the expansion of populations of interest to include areas outside of ICUs (CDC, 2019; Herzig et al., 2015). Intentional non-reporting, or incorrect reporting of infection data, may result in civil monetary penalties or exclusion from Medicare or Medicaid QRPs (CDC, n.d.-b; Herzig et al., 2015; U.S. Centers for Medicare & Medicaid Services, 2020).

CMS enforces standardized reporting of HAIs through the CDC's National Healthcare Safety Network (NHSN) (CDC, n.d.-f). This is the most widely used HAI tracking system in the country. NHSN releases annual progress reports of the HAIs most frequently reported by U.S. healthcare facilities. These published reports help gauge the progress of HAI prevention efforts at the state and national levels and identify areas that require assistance (CDC, n.d.-f). NHSN users must comply with the protocols, standardized HAI definitions, and criteria set by the CDC. The standardization of HAI definitions and baselines ensures reliability and comparability of data at all levels (CDC, n.d.-a). Failure to comply results in NHSN enrollment revocation (CDC, n.d.-b).

The CDC regularly reviews their HAI definitions within NHSN and makes improvements in accordance with the latest evidence-based (EB) science and consumer feedback (CDC, 2017). The CDC most recently updated their HAI definitions in 2015 and established new standardized infection ratio (SIR) baselines to reflect those changes. Data in which standardized HAI definitions and predictive models are used are more easily interpretable than comparisons made using different baselines (CDC, n.d.-a). To facilitate a more standardized approach to public reporting, the HAI progress reports started using 2015 baseline data and methods of risk adjustment in 2016 (CDC, 2020).

Concerted state and federal HAI prevention efforts have been put in place, such as mandatory public reporting of HAI rates and provisional financial reimbursements based on facility-specific HAI performance (Septimus & Moody, 2016). The threat of program exclusion and monetary penalties serves as motivation for healthcare facilities to maximize HAI prevention efforts and ensure accurate and systematic collection and reporting of HAI data. Furthermore, the more recent improvements in HAI surveillance should reveal the true efficacy of HAI prevention programs and lead to more accurate HAI cost and incidence data in the future.

The U.S. has made considerable progress in the prevention of HAIs; however, more work needs to be done. Approximately one in 32 hospitalized patients has a HAI at any given moment (National Center for Emerging and Zoonotic Infectious Diseases, Division of Healthcare Quality Promotion, n.d.-a). This underscores the need for improved HAI prevention practices in U.S. hospitals. Although full engagement is required between public health agencies at the federal, state, and local levels to reduce HAIs, prevention occurs at the facility level. Research suggests that EB prevention collaboratives are key to sustaining and expanding HAI prevention progress within healthcare facilities nationwide (Herzig et al., 2015; National Center for Emerging and Zoonotic Infectious Diseases, Division of Healthcare Quality Promotion, n.d.-a).

Central Lines and CLABSI Rates

CLABSI is a surveillance definition used by the CDC's NHSN to describe bloodstream infections that develop in patients who have undergone CL placement (Haddadin, Annamaraju, & Regunath, 2022; Septimus & Moody, 2016). A CL is a central venous catheter (CVC) that is peripherally inserted into a large, central vein (usually the internal jugular, subclavian, or femoral), and advanced until it terminates in the right atrium or near the heart in the superior or inferior vena cava (Septimus & Moody, 2016). Hospitals routinely use CLs to treat their patients. They are employed for the purposes of medication administration, diagnostic procedures, monitoring, and lab draws. Due to their invasive nature and the vulnerable patient population that requires them, CLs carry the risk of nosocomial infections (Perin, Erdmann, Higashi, & Sasso, 2016).

The two main sources of CL contamination that result in CLABSIs include the following: (1) Insertion site colonization with organism migration along the external catheter surface, which is the most common source within the first week of CL placement; and (2) Direct contamination of CL hubs leading to internal colonization and consequent CLABSI; which is the most common source of infection in CLs that have been in place for a minimum of one week. Less frequently, CLs can become contaminated from another site of infection and even more seldomly from contaminated intravenous (IV) fluids (Septimus & Moody, 2016).

A laboratory confirmed bloodstream infection (LCBI) is made when a CL has been in place for a minimum of two calendar days on the date of diagnosis (Septimus & Moody, 2016). The CL must also be in place the day of or the day prior to the culture (Chopra, n.d.). In addition, the following criteria must also be met for confirmation of LCBI: (1) The patient must have a recognized pathogen cultured from one or more blood cultures (a single blood culture for an organism not identified as common skin flora, and two or more blood cultures for organisms identified as common skin flora), and the microorganism must not be related to another site of infection; and (2) The patient must present with one or more of the following signs or symptoms: fever exceeding 38 degrees Celsius, chills, and hypotension (Haddadin et al., 2022; Septimus & Moody, 2016).

Statement of Problem

CLABSIs continue to be problematic within U.S. hospitals even though they are a preventable harm. CLABSIs are the number one complication of CVC use, with over 250,000 cases occurring in the United States each year (Aloush & Alsaraireh, 2018). Treatment-related costs exceed $2 billion annually and associated mortality rates run between 12% and 25% (Merrill, Sumner, Linford, Taylor, & Macintosh, 2014). Every case places an estimated $45,000 burden on the U.S. healthcare system and increases lengths of hospital stay by up to three weeks (Aloush & Alsaraireh, 2018; Parks, 2018) . In 2009 the CDC introduced general CLABSI reduction and prevention guidelines, which helped to significantly reduce CLABSI rates (Pathak, Gangina, Jairam, & Hinton, 2018). A progress report released by the CDC shows a 50% decrease in the number of CLABSIs reported by U.S. hospitals from 2008 to 2016. The CDC's most recent HAI report from 2019 shows a 7% decrease in CLABSIs and a 3% decrease in CL utilization days between 2018 and 2019 (National Center for Emerging and Zoonotic Infectious Diseases, Division of Healthcare Quality Promotion, n.d.-b) . Nevertheless, approximately one quarter of a million CLABSIs occur each year, with 30,100 of those infections occurring within acute care hospitals alone (Pathak et al., 2018).

Research suggests that the use of CL bundles, in combination with educational strategies and employee training, provides the most effective means to reduce CLABSIs in hospitals (Aloush & Alsaraireh, 2018; Furuya et al., 2016; Merrill, Sumner, Linford, Taylor, & Macintosh, 2014; P. J. Pronovost, Watson, Goeschel, Hyzy, & Berenholtz, 2016). Moreover, the implementation of these best practices has the potential to save an estimated 5,520 to 20,239 lives every year (Barnes et al., 2015). Studies also show a statistically significant correlation between nurse adherence to bundled interventions and CLABSI rates when controlling for factors such as education (Aloush & Alsaraireh, 2018; Furuya et al., 2016; Merrill et al., 2014). CLABSI prevention protocols have been adopted nation-wide; however, bundled interventions and nurse compliance varies (Furuya et al., 2016; Merrill et al., 2014; Pronovost et al., 2016). This indicates the need for nurse-led collaboratives that use standardized EB approaches to prevent CLABSIs and educate nursing staff how to properly carry out the interventions. Thereby, reducing patient morbidity, mortality, duration of stay, and healthcare costs (Pronovost et al., 2016).

Statement of Purpose

The purpose of this study was to determine if a nurse-led collaborative that focused on CLABSI reduction using EB prevention strategies, with an emphasis on maintenance bundles, in the form of a Central Line Adult Point Prevalence Tool (CLAPPT) was successful in decreasing CLABSIs at a rural Midwestern hospital. Nurse compliance with the CLAPPT following formal education was also explored.

A retrospective study using a pretest-posttest design was conducted to evaluate previously collected data on CLABSI rates before and after the inception of CLAPPT as well as nurse adherence with the interventions. A convenience sampling technique was used that included all patients throughout the hospital who had an indwelling CVC from January 1st of 2019 to April 30th of 2021. A convenience sample was also used to collect data on the results of formal nurse education and nurse compliance with the interventions. All nurses who were required to perform CLABSI prevention interventions on their assigned patients within designated units throughout the hospital during the study period have been included in the study.

Introduction of Theoretical Framework

Kurt Lewin, a German-American psychologist, created the theoretical change model in 1947; which is widely used today to facilitate organizational change (Manchester et al., 2014). Lewin's change theory consists of the following three stages: (1) unfreeze, (2) change, and (3) refreeze (Manchester et al., 2014). For unfreezing to occur, there must be a recognized need for change. Once the need for change is understood, staff are willing to break old habits and become receptive to learning new ways to accomplish their goals. The change stage, oftentimes referred to as the "moving stage," is when change takes effect. The final stage, known as refreezing, occurs when the practice change has been adopted and the new standards maintained within the current work culture (Manchester et al., 2014).

The purpose of this study was to determine if a nurse-led collaborative that focused on CLABSI reduction using EB prevention strategies, with an emphasis on maintenance bundles, in the form of a CLAPPT was successful in decreasing CLABSI rates at a rural Midwestern hospital. Nurse compliance with the CLAPPT following formal education was also explored. To accomplish these goals, the nursing staff needed to recognize the need for change, implement the change, and adopt the change into the current work culture. For these reasons, Lewin's three-step change model served as an appropriate framework to guide nursing staff throughout the change process.

Lewin's change theory was used to educate and train staff on the use of the tool to facilitate its implementation and increase nurse compliance with the interventions. A retrospective analysis of CLABSI rates pre- and post- CLAPPT implementation and nurse compliance was performed. The expected outcomes were to determine the efficacy of the CLAPPT intervention in the reduction of CLABSIs and the effectiveness of formal nursing education as it pertains to compliance, and to meet the national benchmark for CLABSI rates. Thus, adding to hospital data through the identification of effective CLABSI prevention efforts. The utilization of Lewin's change theory to implement the interventions and promote adherence among nursing staff in the reduction of CLABSIs will be explored further in the following chapter.

Chapter Two

CL use is the most frequent cause of nosocomial bloodstream infections, carrying a 2.27-fold increased risk of mortality (Barnes et al., 2015; Parks, 2018). Although estimates vary, CLABSI costs can exceed $45,000 per incident, making it the costliest HAI (Parks, 2018; Septimus & Moody, 2016). One in four patients who develop a CLABSI will die, which also makes it the deadliest (McCraw, Crutcher, Polancich, & Jones, 2018; Parks, 2018). These staggering statistics notwithstanding, CLABSIs are highly preventable and increased attention has been focused on their prevention in recent years. Research shows that 65% to 70% of CLABSIs are now preventable with the consistent application of EB strategies over time (Barnes et al., 2015; Septimus & Moody, 2016). Prevention strategies include CL insertion and maintenance bundles, special approaches, staff education, and fostering a culture of improved safety and adherence to the bundled interventions (Barnes et al., 2015; Septimus & Moody, 2016; Whited & Lowe, 2013).

Early CLABSI project prevention goals were often described as "targeting zero." However, it has become evident over the years that CLABSI prevention is unfeasible in all situations. As such, the focus of prevention goals has shifted over time to a more gradual improvement approach to bring and sustain CLABSI rates "near zero" (Barnes et al., 2015). According to the National and State Healthcare-Associated Infections 2019 Progress Report, U.S. CLABSI rates have decreased by 50% over the past decade (Parks, 2018). Such progress is reassuring and undeniably the result of dedication and hard work. However, more work needs to be done to get CLABSI rates closer to zero.

Population of Interest

The ICU patient population is at an increased risk for developing CLABSIs. Forty eight percent of U.S. ICU patients have CLs, resulting in 15 million central line days per year (Agency for Healthcare Research and Quality, 2018). Additionally, an estimated 28,000 ICU patients die from CLABSI annually (Agency for Healthcare Research and Quality, 2018). Ergo, it is easy to understand why ICUs have been the focus of CLABSI research over the past two decades (Barnes et al., 2015; Septimus & Moody, 2016; Whited & Lowe, 2013). However, more recent studies have shown that CLABSI rates may be similar, if not worse, in non-ICU settings (Barnes et al., 2015; Septimus & Moody, 2016; Whited & Lowe, 2013).

According to research published by Marschall et al. (2007), CLABSI rates in non-ICU wards were comparable to those in ICUs across the United States despite lower CL usage. Another study conducted by Climo et al. (2003), compared CL incidence between ICU and general medical units. The researchers found that while usage and prevalence of CLs were higher in the ICU, the overall number of CLs was highest among non-ICU wards, accounting for 70% of the total number of CLs hospital-wide (Whited & Lowe, 2013).

CMS HAI facility reporting requirements began in 2011 with the initial focus limited to CLABSIs in ICUs. It was not until January of 2015 that they expanded their CLABSI reporting requirements to include acute inpatients in adult and pediatric general medical and surgical wards (CDC, 2019; Herzig et al., 2015; Septimus & Moody, 2016). This deficit in the literature demonstrates a need for adequate research in non-ICU patient populations. Furthermore, it is necessary to re-examine current guidelines to ensure the latest EB research is being translated into practice with an emphasis on patient-centered care.

CLABSI Guidelines

Numerous CLABSI prevention guidelines have been established over the years. They have come in the form of various recommendations, toolkits, best practices, bundles, and protocols. CLABSI prevention programs utilize guidelines that are based on the highest level of scientific research and systematically reviewed for implementation by medical professionals in healthcare delivery settings. A CLABSI prevention bundle is most accurately defined as a group of EB practices that produce better patient outcomes when used together, rather than individually (Barnes et al., 2015; Septimus & Moody, 2016). The Institute for Healthcare Improvement (IHI) became a pioneer in CLABSI reduction by introducing the first CLABSI prevention bundle for CL insertion in 2001 (Barnes et al., 2015). Many organizations have since followed suit, including the CDC, Agency for Healthcare Research and Quality (AHRQ), Association for Professionals in Infection Control and Epidemiology (APIC), TJC, Healthcare Infection Control Practices Advisory Committee (HICPAC), and the Infectious Disease Society of America (IDSA), among others (Barnes et al., 2015). Insertion bundles follow a checklist to guarantee compliance with the EB infection prevention strategies to reduce CLABSIs.

CL insertion bundles typically include variations of the following components:

1. Performance of hand hygiene.
2. The use of chlorhexidine gluconate (CHG) alcohol for site preparation.
3. The use of maximum sterile barrier precautions during CL insertion.
4. Appropriate site selection.

5. Use of ultrasound guidance (CDC, n.d.-c; Septimus & Moody, 2016).

The post-insertion period also poses many opportunities for risk of infection. CLs may be in place for weeks or months and are subject to frequent manipulation by various healthcare workers for the purposes of fluid, nutrition, and medication administration, as well as lab draws. Every time a CL is accessed, there is an opportunity for the introduction of microorganisms into the delivery system. This brought about the creation of the CL maintenance bundle. The CDC introduced the most widely accepted CLABSI prevention guidelines, replete with post-insertion care recommendations, in 2002 (Bell & O'Grady, 2017; O'Grady et al., 2002). The guidelines were created for healthcare providers who insert CLs, as well as those responsible for infection control and surveillance in hospital, outpatient, and homecare settings (O'Grady et al., 2002). Postinsertion bundles typically consist of variations of the following components:

1. Disinfection of catheter hub prior to CL access.
2. Prompt removal of catheters when no longer needed.
3. Bathing intensive care unit patients over two months of age with CHG daily.
4. Use of CHG-impregnated dressing for CLs in patients over two months of age.
5. Minimization of unnecessary CL manipulation (i.e., lab draws through CLs for convenience).
6. Transparent dressing changes and performance of site care with a CHG-based product every five to seven days, or every two days for a gauze dressing.
7. Immediate dressing changes when dressing becomes damp, loose, or visibly soiled.

8. Replacement of administration sets not used for blood, blood products, total parenteral nutrition (TPN), or lipids at intervals not exceeding 96 hours.
9. Replacement of administration sets used for blood, blood products, or lipids every 24 hours (CDC, n.d.-c; Septimus & Moody, 2016).

Special approaches, including the use of antimicrobial impregnated catheters, CHG impregnated caps to cover connectors, and antimicrobial lock solutions, may be considered when CLABSIs persist despite use of insertion and maintenance measures (CDC, n.d.-c; Septimus & Moody, 2016).

Numerous studies have shown that CL insertion bundles lower CLABSI rates (Furuya et al., 2016; P. J. Pronovost et al., 2016; P. Pronovost et al., 2006). However, much less is known about the role of postinsertion bundles in CLABSI prevention. They have been included in some CLABSI reduction studies in which a high rate of insertion bundle compliance exists (Dumyati et al., 2014; Guerin, Wagner, Rains, & Bessesen, 2010). It is also difficult to study maintenance bundles independently, as they are implemented in settings where CL insertion bundles have already been established. Even so, research findings have demonstrated further reductions can be achieved with the addition of and adherence to maintenance bundles (Dumyati et al., 2014). This warrants the need for further research on the impact of maintenance bundles in CLABSI prevention.

Literature Review

CLABSI Reduction

Central line insertion bundles. A state-wide safety initiative, better known as the Michigan Health and Hospital Association Keystone Center for Patient Safety and Quality Keystone ICU project, was a pivotal study in the literature regarding CLABSI prevention. This AHRQ funded project began as a pilot patient-safety program that was trialed at Johns Hopkins Medical Institutions. Shortly thereafter, it grew into a successful collaborative effort to reduce CLABSIs in Michigan ICUs (P. Pronovost et al., 2006).

P. Pronovost et al. (2006) sought to improve intensive care in Michigan hospitals by establishing a culture of safety and reducing CLABSIs with EB interventions. VAP reduction and improving compliance with EB ventilator care were additional objectives of the study, of which further mention was not warranted for the purposes of this review. The study took place over a two-year period from October of 2003 to September of 2005. It began with a six-month baseline period, followed by a three-month implementation period for each intervention, and concluded with a follow-up period that continued for up to 18-months postimplementation. The CLABSI reduction efforts consisted of implementing a comprehensive unit-based safety program and EB CL infection prevention interventions (P. Pronovost et al., 2006).

This was a collaborative prospective cohort study that included the Quality and Safety Research Group of the Johns Hopkins University School of Medicine, the Michigan Health and Hospital Association, and 108 ICUs from 67 Michigan hospitals. IRB approval was granted by the Johns Hopkins University School of Medicine. A convenience sampling technique was used that included all Michigan adult ICUs willing to participate in the Michigan Keystone Project. Convenience sampling was also utilized to include all patients from the participatory units who had a CL in place throughout the study. Hospitals began with the implementation of a unit-based safety program in March of 2004, followed by the EB CL infection prevention interventions in June of the same year, to lower the incidence of CLABSI (P. Pronovost et al., 2006).

The EB CL interventions included a CL insertion bundle, educating clinicians on best practices in CL insertion, placing a CL cart stocked with insertion bundle supplies in each ICU, creating an insertion checklist of best practices to ensure compliance with the bundle components, and empowering nursing staff to interrupt CL insertion procedures during non-emergent situations (P. Pronovost et al., 2006). The CL insertion bundle included hand washing, use of full-barrier precautions during CL insertion, cleansing the skin with chlorhexidine, avoiding CL insertion at femoral site, and removal of all unnecessary catheters. These five bundle components were recommended by the CDC and recognized as having the greatest impact on CLABSI rates with the fewest barriers to implementation (P. Pronovost et al., 2006). Catheter necessity and removal were discussed during daily rounds, and the teams were provided with feedback concerning CLABSI numbers and rates at monthly and quarterly meetings (P. Pronovost et al., 2006).

Prior to the implementation of the interventions, each ICU assembled a leadership team that was educated in the EB science behind the safety program and interventions. Next, they were tasked with disseminating this knowledge to their colleagues. Team leaders were trained via conference calls on a bi-weekly basis. They also received coaching by research staff and attended statewide meetings twice per year. Team leaders received supporting information from their respective hospital's infection-control practitioners regarding efficacy of each bundle component, implementation of the interventions, and data collection. Team members were asked to adhere to the national nosocomial infections surveillance system (NNIS) definition of CLABSI throughout the study (P. Pronovost et al., 2006).

A CL was defined as a catheter that terminated at or near the heart in a great vessel and the number of patient catheter days and CLABSI cases were determined in accordance with NNIS guidelines. The researchers hypothesized that the CLABSI rate would be reduced during the initial three months following the intervention as compared with baseline. They further hypothesized that this observed decrease in CLABSIs would be sustained during the subsequent observation period. Data for number of CLABSIs and catheter days were collected monthly and aggregated into quarters to coincide with the three-month implementation period for each intervention. The quarterly rates of infection were calculated as the number of infections/1,000 catheter-days and assigned categorically in accordance with the date the intervention was implemented (P. Pronovost et al., 2006).

Out of the 108 participating ICUs, four were excluded for not tracking or reporting CLABSIs, catheter-days, or both, and one due to a merger with another participating ICU. The combined data from the merger were included in the analysis. As a result, 103 ICUs reported data, accounting for 1,981 ICU-months and 375,757 catheter-days, that were included in the study. The total number of catheter-days remained relatively unchanged throughout the study (P. Pronovost et al., 2006).

The researchers found a statistically significant decrease in the median rate of CLABSIs/1000 catheter-days from 2.7 infections at baseline to zero infections at three months after implementation of the intervention ($p \leq 0.002$) (P. Pronovost et al., 2006). They also found a statistically significant decrease in the mean rate of CLABSIs/1,000 catheter-days from 7.7 at baseline to 1.4 infections at 16 to 18 months post-intervention ($p < 0.002$) (P. Pronovost et al., 2006). Furthermore, the multilevel Poisson regression model showed a statistically significant decrease in CLABSI rates from baseline with incidence-rate ratios steadily decreasing from 0.62 (95% CI, 0.47 to 0.81) at zero to three months post implementation of the intervention to 0.34 (95% CI, 0.23 to 0.50) at 16 to 18 months (P. Pronovost et al., 2006).

This study demonstrated that a large-scale quality improvement project focused on CLABSI reduction is achievable and can have significant public health implications. The research also suggests that CLABSI related morbidity and healthcare costs can be reduced with successful implementation of the study interventions on a national or global scale. The researchers attribute the success of the project to the existence of a supportive infrastructure that provided necessary funding and properly trained staff. Randomization of the intervention was not feasible due to variations in implementation by each ICU, which reduced the ability to find a causal relationship between the intervention and reduced CLABSI rates. The researchers also list potential underreporting of CLABSIs and lack of baseline data as weaknesses that may have created measurement bias and skewed results. Collection of data on causative organisms was not performed and individual bundle components and adherence with the interventions were not studied. Last, this study was conducted in one state, which may have limited the generalizability of the study findings (P. Pronovost et al., 2006).

In a follow-up quantitative prospective cohort study conducted by P. J. Pronovost et al. (2016), the researchers sought to describe sustained reductions in CLABSI rates in Michigan ICUs 10 years post the inception of the Michigan Keystone project. The interventions responsible for the sustained low infection rates were also examined. This study utilized clinical communities comprised of researchers in patient safety and improvement science from Johns Hopkins Medicine Armstrong Institute for Patient Safety and Quality, Michigan Health and Hospital Association (MHA) Keystone Center, and participating hospitals. IRB approval was granted by the Johns Hopkins University School of Medicine. CLABSI rates were analyzed from 121 intensive care units from 73 Michigan hospitals over a ten-year period (March 2004-December 2013) (P. J. Pronovost et al., 2016).

Improvement teams from each ICU collected monthly data on CLABSIs and catheter-days from their hospital infection control staff. Data reports on infection rates were submitted to MHA until 2012. MHA started importing data in 2012 from NHSN. MHA sent teams quarterly performance reports. The ICU teams convened for annual meetings and connected through numerous conference calls throughout each year to discuss interventions, data, and progress. A conceptual model was utilized to reinforce and incorporate the use of the five EB CLABSI prevention interventions that were previously discussed. The model was employed to strengthen teamwork and communication. It was also used for the purposes of educating and empowering staff concerning patient safety (P. J. Pronovost et al., 2016).

The main outcome measured was infection rates per 1,000 catheter days. ICUs with baseline infection rate data were compared with data collected at the end of the study to determine rates among the individual units. The mean rate of yearly CLABSIs decreased from 2.5 infections/1000 catheter-days in 2004 to 0.76 in 2013 (P. J. Pronovost et al., 2016). It was determined that the significant reduction in CLABSI rates achieved in the initial Keystone ICU project were sustained for 10 years. These findings established a new benchmark for CLABSI rates in ICUs. Furthermore, this rate remained below 1 infection per 1,000 central line-days since 2008. Variability in CLABSI rates also decreased, particularly those with high rates of CLABSI (P. J. Pronovost et al., 2016). Thirty-three percent of ICUs reported CLABSI rates of >3 infections per 1,000 catheter-days at baseline, whereas all ICUs were reporting rates of <3 infections per 1,000 catheter days in 2013 (P. J. Pronovost et al., 2016). A subset analysis discovered that the percentage of ICUs with a mean rate of <1 infection/1,000 catheter-days almost doubled the baseline from 34% in 2004 to 65% in 2013 (P. J. Pronovost et al., 2016). The active participation of hospital leaders and the Keystone Center, in addition to the ongoing surveillance and performance feedback, played key roles in sustained reductions in CLABSIs (P. J. Pronovost et al., 2016).

This was a large-scale study that confirmed that the CLABSI rates that were reported in the initial Keystone ICU project were sustained for the ten-year duration of the study, which set a new benchmark for CLABSI rates amid ICU patients. The results suggest that extensive quality improvement projects are capable of being sustained and adopted into the current work culture. The authors listed the inability to determine which interventions contributed to sustained reductions in CLABSIs, as well as the inability to confirm a causative association between the interventions and the sustained reductions, as study limitations. Additionally, 20% of the quarterly CLABSI data was missing because hospitals failed to submit their data (P. J. Pronovost et al., 2016).

In a similar study, Furuya et al. (2016) focused on the impact of CL insertion bundles on CLABSI rates. The researchers sought to describe CL bundle compliance, as well as the association between CL bundle compliance and CLABSI rates, including the role of each bundle component and the number of components required. This was a quantitative study with a cross-sectional design. A convenience sampling technique was used, and eligibility was extended to all non-VA adult ICUs participating in NHSN. A total of 984 adult ICUs from 632 hospitals and 51 states and territories participated, which made it the largest study of its kind (Furuya et al., 2016). The project received IRB approval from both Columbia University Medical Center and the RAND corporation. This study took place in 2011 and was part of the P-NICER (Prevention of Nosocomial Infections and Cost Effectiveness Refined) annual study. P-NICER evaluates infection prevention and control practices at hospitals nationwide (Furuya et al., 2016).

The participating hospitals completed a web-based survey in which they answered questions about hospital characteristics and ICU-specific infection prevention practices that included written policies for CL insertion bundles and the levels of observed compliance with the bundle in its entirety, as well as with individual bundle components. This study adopted the same CL insertion bundle components that were described in the Michigan Keystone Project: (a) hand hygiene prior to insertion; (b) maximal barrier precautions; (c) chlorhexidine skin antisepsis; (d) optimal site selection (i.e., avoidance of femoral vein in adults); and (e) daily review of line necessity (Furuya et al., 2016). Levels of observed compliance were recorded, categorized, and reported for each hospital. Categories of compliance were listed as excellent (≥95%), usually (75%–94%), sometimes (25%–74%), rarely or never (<25%), or do not know/compliance not monitored (Furuya et al., 2016).

Multivariate Poisson regression analyses were performed (1) to determine levels of observed compliance with the entire CL bundle, as well as with individual bundle components and (2) to determine a relationship between the observed levels of compliance and CLABSI rates (Furuya et al., 2016). In total, 98% of ICUs had adopted CL bundle policies; however, only 69% of ICUs reported ≥ 95% compliance with a minimum of one bundle component (Furuya et al., 2016). Overall, 20% of ICUs reported excellent compliance with all elements, and 49% of ICUs reported that they were usually compliant (≥75%) (Furuya et al., 2016). The statistically significant results showed the greatest reduction in CLABSIs were associated with excellent compliance (>95%) with all five bundle components, IRR = 0.67, 95% CI [0.59–0.77] (Furuya et al., 2016). However, excellent compliance with at least one bundle component was also associated with a statistically significant decrease in CLABSI rates, IRR = 0.77, 95% CI [0.64–0.92] (Furuya et al., 2016). Statistical models in which observed compliance was ≥95% showed the strongest relationships with CLABSI reduction. Whereas models in which observed compliance was <95% produced results that trended in the same direction but showed markedly weaker relationships with lower CLABSIs rates (Furuya et al., 2016). No association between CLABSI rates and simply having a written CL bundle policy was found. Nor was there an association between CLABSI rates and bundle compliance below 75%, although statistical trends suggested each bundle component was protective against CLABSI (Furuya et al., 2016).

The research of Furerya et al. (2016) is notable for being the largest to date to evaluate CL bundle compliance in the United States, which included data from close to 1,000 adult ICUs. This is also the largest study to examine the association between CL bundle compliance and CLABSI rates. The study findings showed a statistically significant association between excellent CL bundle compliance and CLABSI reduction.

In addition, excellent compliance with at least one bundle component was associated with a statistically significant decrease in CLABSI rates. However, the data collected from the participating hospitals was self-reported, which may have introduced self-reporting bias. Furthermore, hospitals that agreed to participate may have been comprised of stronger performers than the non-participatory hospitals with which they were compared, potentially resulting in sample-selection bias. Lastly, the researchers controlled for various factors; however, there was the possibility that unmeasured confounding variables affected the outcomes measured (Furuya et al., 2016).

Maintenance bundles. A study conducted by Guerin et al. (2010) was the first study to show that postinsertion bundles can decrease CLABSI risk in a setting where an increased density of CLABSIs persist despite a high rate of insertion bundle compliance. This was a quantitative study with a quasi-experimental design. Project approval was granted by the Colorado Multiple IRB. The study took place at DVAMC-Denver, a university- affiliated acute care teaching hospital with a reported 5,000 patient admissions and 38,000 patient-days each year. The researchers utilized a convenience sampling technique that included all patients located in the surgical and medical ICUs with an indwelling CL catheter over a 12-month period post intervention implementation. Each ICU had a 1:2 nurse/patient ratio. The nursing staff was required to complete an online training module for the bundled interventions and achieve a minimum score of 80% on a post-quiz. They were also required to attend a four-hour practical training session on the proper techniques for CL access and maintenance that was followed by a competency evaluation. Data collection took place from October 1, 2008, to September 30, 2009, on designated device-days. This began after a six-month pilot phase, during which time the nursing staff gained experience performing the interventions and collecting data for mock device-days (Guerin et al., 2010).

The postinsertion bundle was created by the nursing staff and implemented by a designated IV champion in each of the ICUs. The maintenance bundle interventions consisted of (1) cleaning the insertion site with 2% CHG in alcohol solution for 15 seconds prior to use, (2) application of CHG impregnated sponge placed over the insertion site (changed weekly, unless wet, soiled, or loose), (3) application of a transparent dressing over the CHG sponge (changed weekly, unless wet, soiled, or loose), (4) daily IV tubing changes for parenteral nutrition solutions and every 72 hours for non-parenteral solutions, (5) daily inspection of insertion sites for infection, proper placement, and patency, (6) hand hygiene prior to handling CLs or bundle components, and (7) documentation of CL necessity (Guerin et al., 2010).

Four certified infection preventionists conducted CLABSI surveillance using the CDC's NHSN CLABSI case definitions and device-day measurement methods. This was achieved through medical record review and included every patient with a positive blood culture. A standard form for data collection was utilized. Thereafter, the identified CLABSI cases were sent to the hospital epidemiologist for further review to ensure they met the case definitions set by the institution. Device-day data was compared with data that were collected daily by the IV catheter management team to confirm accuracy (Guerin et al., 2010).

During the preintervention period from October 1, 2006, to September 30, 2008, CL insertion bundle compliance was 94% (Guerin et al., 2010). There were 11,434 patient-days and 4,415 documented catheter-days, resulting in a catheter utilization proportion of 0.39 (Guerin et al., 2010). During this time 25 CLABSIs were identified, accounting for an incidence density of 5.7 CLABSIs per 1,000 catheter days (Guerin et al., 2010). During the intervention period from October 1, 2008, to September 30, 2009, CVC insertion bundle compliance was 93% (Guerin et al., 2010). There were 5,937 patient-days and 2,825 documented catheter-days, resulting in a catheter utilization proportion of 0.48 (Guerin et al., 2010). During this time three CLABSIs occurred, resulting in an incidence density of 1.1 per 1,000 catheter-days ($p < .0001$) (Guerin et al., 2010). The relative risk for CLABSI compared during the pre- and post-intervention period was 0.19 (95% CI, 0.06-0.63; $p = .004$) (Guerin et al., 2010). A calculation adjustment was then made to run statistical analyses under the assumption that the number of catheter-days in the baseline period had an equal utilization proportion to that in the postintervention period. When the statistical tests were repeated under the new assumptions, the relative risk of CLABSI during the intervention period remained significant at 0.23 (95% CI, 0.07-0.77; $p = .017$) (Guerin et al., 2010).

This was the first study to demonstrate CLABSI reduction with a primary focus on postinsertion care in a setting where a high rate of insertion bundle adherence was already established. Another strength of this study is that it also demonstrated that the implementation of interventions developed by nurses can have a high degree of efficacy. The study was quasi-experimental by design. Therefore, the lack of random assignment may have limited the generalizability of the results to larger populations as well as the ability to conclude a causal relationship between the interventions and the outcome. The internal validity of the study may have also been reduced. This study was conducted at a single medical facility, which may have contributed further to decreased generalizability of the research findings (Guerin et al., 2010).

A large scale longitudinal study conducted by Dumyati et al. (2014) also focused on CL maintenance in CLABSI reduction. Additionally, they chose to conduct their research in non-ICU settings. As previously mentioned, postinsertion care and CLABSI prevention outside of ICUs have not been well studied. The purpose of this study was to determine the impact of a multimodal intervention on CLABSI rates in adult non-ICU populations across multiple hospitals with a focus on CL maintenance. This involved establishing a collaborative team to prevent these infections through engagement, formal nursing education, and the implementation and standardization of EB practices for CL line care and maintenance. This was a quantitative study with a quasi-experimental, prospective preintervention-postintervention design that took place in 37 units across six hospitals in Rochester, NY. The hospitals ranged in size from 61 to 739 beds. A convenience sampling technique was used that included all adult patients from select non-ICU units, where CL use was common, who underwent CL placement from April 2008 to December 2012. The select units included combined medical-surgical, ICU step-down, and specialty (e.g., bone marrow transplant, oncology). A convenience sampling technique was also used for the nursing education intervention that included every nurse from the participatory units in the six hospitals under study. To ensure consistency across hospitals, CLABSI prevention education, training, and protocols were standardized and NHSN CLABSI definitions were utilized. This study was approved by the IRB of each hospital prior to project initiation (Dumyati et al., 2014).

This study occurred in three phases–preintervention (baseline), intervention, and postintervention. Phase one occurred from April 2008 to March 2009 (Dumyati et al., 2014). In April, a collaborative team consisting of hospital epidemiologists and infection preventionists (IP) from the participating hospitals was formed. The team convened monthly to discuss education implementation, CLABSI reduction progress, and the necessity for further interventions. Thereafter, each team member was tasked with disseminating information to IPs and frontline staff at his/her respective hospital. The team also created a CL maintenance bundle in accordance with EB guidelines. The bundle included (1) hand hygiene, (2) aseptic technique (scrubbing the port for 10-15 seconds) prior accessing needleless connectors, (3) CL dressing changes, (4) frequency of needleless connector, IV line, and dressing changes, and (5) regular assessment of CL necessity (Dumyati et al., 2014).

The team reviewed the six hospitals' CL policies, after which, they conducted a pre-educational survey of 200 nurses to assess their current knowledge of CL care and maintenance. The survey revealed that only 40 of 200 nurses (20%) reported practicing proper aseptic technique for cleansing the needleless connector (Dumyati et al., 2014). This knowledge gap was addressed by creating new, standardized policies based on current best practices and incorporating them into future educational interventions.
A nursing lecture was held at each hospital to introduce the CL maintenance bundles following six months of CLABSI surveillance. During which time nurses' survey results and baseline CLABSI rates were discussed. Additionally, the team created a CL bundle online educational module that contained information in CLABSI pathology and

prevention. The module concluded with a post-test to assess knowledge of best practices in CL maintenance and a score of 80% was required to pass (Dumyati et al., 2014).

Phase two, the intervention, took place from April 2009 to March 2010 (Dumyati et al., 2014). During this time, the collaborative team identified low engagement by nursing leaders, physicians, and frontline staff. In response, they expanded their team to include nurse educators, nursing leadership, quality and safety staff, a vascular access team, and one hospitalist physician champion to strengthen expertise in the areas of CL management, staff education, and project implementation. The CLABSI prevention educational model was launched throughout each unit across the six hospitals. Module completion was mandatory for all nursing staff, with annual completion required thereafter. The electronically recorded results revealed a 90% completion rate among staff (Dumyati et al., 2014). Additional in-person education with one-on-one competency evaluations, was also provided on select units throughout the intervention phase (Dumyati et al., 2014).

Nurses' compliance with the maintenance bundle was assessed with weekly audits using two data collection tools. A nursing practice audit tool was used for observation of CL dressing changes and access of needleless connectors, and a dressing integrity audit tool was used for the assessment of CL documentation of dressing dates and condition, IV tubing dates, and needleless connector changes. In total, 800 audits were performed, and 250 in-person nursing practice observations were made. The in-person observations allowed for constructive feedback and educational opportunities regarding proper bundle component techniques (Dumyati et al., 2014).

Phase three, the post-intervention phase, took place from April 2010 to December 2012 (Dumyati et al., 2014). During this phase, the nursing survey was readministered and compared with baseline data to assess knowledge retainment. Nursing staff from participatory units attended an educational workshop to discuss their progress in the initiative. Project experiences and challenges were also shared. A thorough review of the shared experiences revealed that the integration of standardized education into the daily routine was key in the development of a self-sustained CLABSI prevention initiative. Through continued discussions it became evident to the collaborative team that an improved understanding of the factors that contribute to CLABSIs was needed to guide future CLABSI prevention efforts. This led to an in-depth case review during year four of the study that included all CLABSIs that occurred on participating units. This review identified contributing factors, which increased staff awareness of CLABSI related morbidities and led to the development and implementation of new interventions to preclude future complications (Dumyati et al., 2014).

All CLABSIs from designated units were entered into the NHSN database. During the post-intervention phase, a two-step audit was performed by a third-party certified IP with experience in NHSN definitions and chart review for purposes of reporting accuracy and validation, utilizing the NHSN Validation Guidance Toolkit. When discrepancies in reporting were identified, constructive feedback was provided to the IP from the unit in question. Hospitals reported CL-day estimates by collecting a weekly device use ratio (DUR). This was defined as the number of patients with a CL divided by the total number of patients per unit. The IP was tasked with collecting and reporting the DUR data in accordance with NHSN protocols (Dumyati et al., 2014).

Daily project management was assigned to a coordinator to ensure precise data collection and reporting. This was achieved through regularly scheduled rounds where DUR data sheets were collected and reviewed for accuracy. Erroneous reporting was immediately addressed with the unit manager. Data was retrieved from NHSN on a quarterly basis and provided to the collaborative team. The data included CLABSI rates, number of days since last infection, and number of CLABSIs compared between units and hospitals. CLABSI rate (number of cases divided by number of line-days) was calculated by hospital and then stratified by unit (Dumyati et al., 2014).

The overall CLABSI rate was 2.6/1000 line-days (95% CI, 2.2-3.0) during the pre-intervention phase (Dumyati et al., 2014). A time series analysis showed a decline in CLABSI rates during the intervention and post-intervention phases. The overall rate decreased by 50% from 2.6/1000 to 1.3/1000 CL days postintervention; which was statistically significant ($p = .0179$), with the lowest rates occurring in phase three (Dumyati et al., 2014). The greatest absolute reduction in CLABSI rates occurred in specialty care units (RR, 0.40; 95% CI, 0.29-0.55; $p < .0001$), followed by the combined medical-surgical units (RR, 0.51; 95% CI, 0.38-0.68; $p < .0001$) (Dumyati et al., 2014). Overall CL usage remained the same during the three phases of the study. The pre-intervention nurse survey revealed that only 40 of 200 of nurses (20%) reported proper scrubbing of the needleless connector for 10-15 seconds (Dumyati et al., 2014). Following formal education, hands-on training, audits, and feedback, this proportion increased to 70% (167 of 238 nurses) (Dumyati et al., 2014). Audit data showed 82% compliance with proper technique of scrubbing needleless connectors and >90% compliance with other bundle components (Dumyati et al., 2014).

Dumyati et al. (2014), discussed sustainable CLABSI reduction in non-ICU populations across six diverse hospitals with a multimodal intervention that involved engaging and educating nursing staff on EB bundles with emphasis on CL maintenance. The intervention also included the provision of feedback regarding CLABSI rates and a review of CLABSI cases. Additionally, CL care, maintenance policies, and education were standardized across all hospitals, which ensured that each patient received the same EB care regardless of hospital location. This study had a quasi-experimental design that may have reduced study generalizability and internal validity and resulted in conclusions about causality that were less definitive. Furthermore, this study did not measure factors beyond education and feedback, which may have contributed to a reduction in CLABSI rates. Lastly, physician engagement and the change process differed across the participating hospitals, which may have also had an impact on CLABSI rates (Dumyati et al., 2014).

Review

In summary, CLABSI is the number one cause of HAIs, resulting in increased patient morbidity, mortality, and healthcare costs, despite being a preventable harm. Several studies suggest that the use of EB CL bundles, and compliance with the components therein, is the most effective way to reduce CLABSIs in the hospital setting (Dumyati et al., 2014; Furuya et al., 2016; Guerin et al., 2010; P. J. Pronovost et al., 2016; P. Pronovost et al., 2006). These studies have also demonstrated that creating a culture of safety through staff education and engagement, data feedback, and increased CLABSI awareness has played a vital role in CLABSI reduction and establishing new CLABSI benchmarks (Dumyati et al., 2014; Furuya et al., 2016; Guerin et al., 2010; P. J.

Pronovost et al., 2016; P. Pronovost et al., 2006). Furthermore, these studies have reported the positive impact of CL bundles on CLABSI rates when implemented as part of collaboratives (Dumyati et al., 2014; Furuya et al., 2016; Guerin et al., 2010; P. J. Pronovost et al., 2016; P. Pronovost et al., 2006).

According to the literature, ICU patients are at increased risk for developing CLABSIs (Dumyati et al., 2014; Furuya et al., 2016; Guerin et al., 2010; P. J. Pronovost et al., 2016; P. Pronovost et al., 2006). In addition, numerous studies have shown that CL insertion bundles lower CLABSI rates (Dumyati et al., 2014; Furuya et al., 2016; Guerin et al., 2010; P. J. Pronovost et al., 2016; P. Pronovost et al., 2006). For these reasons, most CLABSI prevention research has focused on the impact of CL insertion bundles on CLABSI rates in ICU populations. CLABSI prevention outside of ICUs has not been well studied and even less is known about the impact of CL maintenance bundles on CLABSI rates in both ICU and non-ICU patient populations. Based on this literature review, further research on CLABSI prevention with the use of bundled interventions that include patient populations outside of the ICU setting, with a focus on CL maintenance, is warranted. Further emphasis should be placed on creating a culture of safety that promotes nurse adherence with the interventions.

The purpose of this study was to determine if a nurse-led collaborative that focused on CLABSI reduction using EB prevention strategies, with an emphasis on maintenance bundles, in the form of a CLAPPT was successful in decreasing CLABSI rates at a rural Midwestern hospital. Nurse compliance with the CLAPPT following formal education was also explored. This DNP project will translate EB research into practice to reduce CLABSIs. Thereby, adding to the literature, advancing the discipline of nursing, and providing grounds for further research in the field. The EB interventions should be implemented with the infrastructure of the healthcare institution, its staff, the population of interest, and the most recent standards of care in mind.

Theoretical Framework

Lewin's change theory (1947) was utilized to help guide the implementation of the hospital's practice change and promote compliance with the interventions to decrease CLABSI rates. Lewin's change model consists of the following three stages: (1) unfreeze, (2) change, and (3) refreeze (Manchester et al., 2014).

During the unfreezing stage, staff must first recognize the need for change. Only then, will they be willing to break old habits and become receptive to learning new ways to accomplish their goals (Manchester et al., 2014). In the setting of this Doctor of Nursing Practice (DNP) project, a standardized infection ratio (SIR) exceeding 1.0 indicated that a change was necessary.

HAI prevention progress data that is reported to the NHSN are measured using a summary statistic known as SIR (CDC, 2021). The CDC calculates a SIR for each facility that is based on hospital and patient characteristics, as well as types of services rendered. It is also used to track the progress of HAI prevention over time (CDC, 2021; Salmasian et al., 2021). The national and state SIR are calculated by dividing the number of reported infections nationwide and statewide, respectively, by the number of predicted infections based on baseline data of a previous year. The CDC does adjust the SIR for risk factors that are commonly associated with variances in infection rates. In the case of CLABSI, the type of healthcare facility, catheter type, number of beds, type of unit, and medical school affiliation are taken into consideration when applicable. This information, in addition to the number of reported indwelling device days, determines how many infections can mathematically be expected (CDC, 2021; Salmasian et al., 2021). A SIR value of 1.0 represents the average medical facility in the nation. To this end, hospitals aim for a SIR of <1.0, which indicates that fewer HAIs were observed than predicted. Conversely, a SIR exceeding 1.0 indicates that more HAIs were observed than predicted (Salmasian et al., 2021).

To ensure the nursing staff recognized and understood the need for change, they needed to be made aware of the discrepancy between the desired state, a SIR value below 1.0, and the current state, a SIR value in excess of 1.0, as well as the serious implications this posed on the patients, staff, hospital, and community at large. The nursing staff were responsible for carrying out the proposed changes. As such, it was essential they were the primary focus of the change process. For unfreezing to occur, there must be a recognized need for a change. Mandatory educational and training sessions helped solidify the staff's understanding of the need for a practice change and prepared them to appropriately execute the necessary interventions that occurred in the implementation stage. This was achieved by organizing the Harms Prevention (HP) event. HP was a hospital-wide, mandatory educational event for nurs that focused on CLABSI prevention, which included the updated CLABSI protocols and hands-on CL dressing change training. Afterwards the nurses took a ten-question quiz to determine the effectiveness of the education.

The second stage of Lewin's change theory (1947) involves executing the change. Employees must see the change as an investment to endure the learning curves and setbacks that accompany it (Manchester et al., 2014). In this case, the change required nursing staff to implement the new protocols, which included CLABSI bundled interventions, to reduce CLABSIs.

To ensure successful integration of the interventions, it was imperative that the nursing staff received formal education on the individual components of the interventions, including their role in CLABSI prevention. Staff are more likely to demonstrate acceptance of and willingness to actively support and participate in the change process if both the smaller objectives and the larger overarching goal are made explicitly clear (Shirey, 2013). In the case of this DNP project, the overall, desired outcome was to achieve a SIR of <1.0. The smaller objectives included implementation of the interventions and staff demonstration of a desirable level of compliance with those interventions.

The third, and final stage of Lewin's change theory (1947) is the refreezing stage. The goal in the refreezing stage is for staff to adopt the change into the current work culture and develop ways to sustain those changes (Manchester et al., 2014). The final stage is achieved once staff adheres to and maintains the new practice change of CLABSI bundle compliance. This stage was evaluated through review of staff compliance with the CLABSI prevention interventions over a prolonged period following the introduction of the practice change.

Chapter Three

Methods

Purpose

According to the literature, CLABSI is the leading cause of nosocomial infections (Barnes et al., 2015; Parks, 2018). It is also the deadliest and costliest of the HAIs (McCraw et al., 2018; Parks, 2018; Septimus & Moody, 2016). Numerous studies have revealed that the use of CL insertion bundles in a setting with a high rate of bundle compliance is the most effective means to reduce CLABSIs in the hospital setting (Dumyati et al., 2014; Furuya et al., 2016; Guerin et al., 2010; P. J. Pronovost et al., 2016; P. Pronovost et al., 2006). The literature also suggests that even further reductions can be achieved with the addition of and adherence to CL maintenance bundles (Dumyati et al., 2014; Guerin et al., 2010).

The purpose of this study was to determine if a nurse-led collaborative that focused on CLABSI reduction using EB prevention strategies, with an emphasis on maintenance bundle, in the form of a CLAPPT, was successful in decreasing CLABSI rates at a rural Midwestern hospital. Nurse compliance with the CLAPPT following formal education was also explored.

Project Approval

This DNP project received hospital Institutional Review Board (IRB) approval on January 13, 2021, prior to the implementation of this project. University IRB approval was not required as this was a retrospective study with preexistent data that was stripped of all identifying information. The participants are referenced by numeric designation only. Therefore, it was determined by both the hospital and university IRBs that participant consent was not needed for the purposes of this research. University IRB documents may be viewed in Appendix A. To protect hospital privacy, all hospital identifiers, including facility IRB approval documents, were excluded from this project. University IRB acknowledges receipt of hospital IRB project approval.

Sample

Sample data used in this project were pre-existing. Inclusion and exclusion criteria were established by the hospital's Infection Preventionist (IP) in accordance with the NHSN guidelines set forth by the institution at the time of data collection. For review of CLABSI rates, a convenience sampling technique was used that included all inpatients from the designated units who had an indwelling CVC from January 1, 2019, to April 30, 2021. The designated units included ICU, IMCU, medical, cardiac, neurology, surgical, orthopedic, and physical rehabilitation. Per NHSN guidelines, CLABSIs were calculated using the number of LCBIs per 1,000 CL days instead of the patient total. Therefore, the sample was converted to 12,962 CL days for meaningful use. No patient with an indwelling catheter who met the above criteria was intentionally excluded from this study and all CL days were utilized for the purpose of this project. Of note, on rare occasions a patient may not have been present during device audits due to scheduled imaging or a procedure. In this case, the IP or another auditor would circle back later that day or the following day to complete the audit. The entire patient population with an indwelling CVC from the designated units during the 28-month study period was included.

A convenience sample was used for review of nursing staff compliance with the CLAPPT following formal education that included all patients with an indwelling CVC from the designated units who were present during regularly scheduled CVC device audits, or device days, from January 1, 2019, to April 30, 2021. The audits were completed during the day shift by the IP during the months of the pre- to early pandemic period (January 2019 to March 2020), and by each unit's charge nurse during the months of the pandemic period (March 2020-April 2021). Device days occurred on Monday, Wednesday, and Friday for patients in the ICU and IMCU, and on Tuesday and Thursday for the medical, cardiac, surgical, neurological, orthopedic, and physical rehabilitation units. A total of 8,818 direct patient and electronic medical record (EMR) observations were made, all of which were included in this study.

Compliance with the CLABSI prevention interventions involved participation from the nursing staff, which included all registered nurses (RNs), licensed practical nurses (LPNs) and care aides (CAs) who were required to provide CL care for their patients in the designated units of the hospital during the study period. The initial audit data was collected under each respective patient's account. The IP later entered the data into an excel spreadsheet where it was stripped of all identifying information. The nurses remained anonymous, and no exclusion criteria were specified.

A convenience sampling method was also used to collect data on the results of formal nurse education. The CLABSI prevention education occurred as part of the mandatory hospital-wide HP event that took place over a three-day period in February of 2020. A total of 237 RNs, LPNs, and CAs attended HP and participated in the post-test that was designed to determine the effectiveness of the education. The results from all 237 post-tests were included in the study. All participants remained anonymous, and non-nursing staff were excluded.

Design

This DNP project used a retrospective pretest-posttest design to compare both CLABSI rates, as well as nurse compliance with CLABSI prevention interventions, before and after inception of the CLAPPT. In addition, a posttest design was used to determine the effectiveness of the CLABSI prevention education. The author kept in regular contact with the IP via email, text, telephone calls, and in-person communication throughout the course of this research project. The author also attended several monthly CLABSI prevention meetings, met with the Clinical Educators, and helped organize and run the CLABSI station at the HP event. This project used a retrospective approach; therefore, it was imperative that the author gain an immersive understanding of the CLABSI prevention collaborative, as well as the events leading up to the intervention, prior the implementation of this research.

Procedures and Measures

Prior to this Research

The need for an intervention targeting CLABSI prevention was first identified in 2019 by the hospital's IP. During that year, the hospital experienced an unprecedented rate of four CLABSIs in a 12-month span. The following year in 2020, the hospital experienced three CLABSIs in the first two months alone. This uptick in CLABSIs resulted in SIR values of 1.88 and 2.56 for the months of January and February, respectively, that exceeded the NHSN SIR threshold of 1, as well as the SIR goal of 0.69 set for the institution. This prompted a call to action that resulted in a nurse-led practice change to lower CLABSI rates and reduce the SIR to an acceptable level.

The practice change intervention began with the IP's recommendations for quality improvement in February of 2020. The IP proceeded by convening with the CLABSI team to develop a CLABSI prevention action plan. The CLABSI team was comprised of Nurse Managers and Directors, Clinical Educators, the Director of Nursing, the Chief Nursing Officer, and the Director of Quality Control. They conducted an extensive review of hospital CLABSI data and the current literature regarding CLABSI prevention. It was determined that CLABSI rates persisted despite a high rate (100%) of CL insertion bundle compliance. The review also revealed the CL maintenance bundle protocols needed to be updated and nurse compliance with post-insertion care was lacking. The collaborative team responded by revising the CL maintenance bundle to reflect the latest EB standards from the CDC. The interventions were then reintroduced using the Central Line Adult Point Prevalence Tool (CLAPPT) (Appendix B) to promote standardization of and compliance with recommended practices. According to AHRQ (2020), the use of CLABSI tools, such as checklists, have been successful in reducing CLABSIs when used in combination with comprehensive hospital safety programs.

Prior to the intervention, completion of the CLABSI prevention interventions was documented as part of each patient's EMR. Through an extensive review of patient charts and rounding audits it was found that these interventions were often overlooked, or incorrectly reported as complete. This lack of conformity could be attributed to several factors. The documentation for the interventions was not streamlined and nursing staff were required to access several different computer programs to complete documentation of the interventions. Furthermore, not all intervention fields were included in the EMR. Therefore, documentation was not performed or tracked for every intervention, leaving little to no means for staff accountability. After conducting a review of the current literature regarding CLABSI prevention, the team determined that incorporating the revised protocols into a paper handoff tool to be utilized during bedside shift report would promote staff accountability, standardized care, and patient safety (Maxson, Derby, Wrobleski, & Foss, 2012). Bedside shift report would also support a patient-centered approach and increase patient satisfaction by allowing the patient to be involved in his or her plan of care (Maxson et al., 2012).

The CLAPPT was created to fulfill the purposes of the handoff tool. It served as a checklist to guide the implementation of the CLABSI prevention efforts and encourage compliance with the EB interventions to reduce CL infections.

During shift report, both the off-going and on-coming nurses reviewed the checklist together to ensure each item had been addressed. A signature was required of both nurses to verify compliance. Completion of each item was marked as Yes, No, or Nonapplicable (N/A). Immediate follow-up by the IP or unit charge nurse was to be performed if an item had been marked as “No.”

The CLAPPT included the following interventions:

1. Dressing clean, dry, and intact.
2. Dressing dated.
3. CHG gel pad is placed with contact to skin around entire central line insertion site.
4. Transparent dressing changed when wet, soiled, or loose and within 7 days; gauze dressing changed when wet, soiled, or loose and within 2 days.
5. IV tubing is dated with time when it is hung.

6. IV tubing is not overdue for change:
    - 96 hours if continuous fluids
    - 24 hours if disconnected/intermittent
    - 24 hours if TPN, lipids/propofol
    - 4 hours if blood
7. Alcohol port protectors (Curos caps) are placed on all injection ports of the central line and the central line tubing.
8. Daily evaluation of clinical necessity of central line is completed with prompt removal of any line determined to be unnecessary.
9. Patient and/or family received Central Line Associated Bloodstream Infection (CLABSI) prevention education located in CareNotes, IBM Watson Health prior to CL placement or ASAP after line placement.
10. Patient received CHG bath in last 24 hours and documentation reflects this.

Protocol Updates

CHG gel dressings. Due to an increase in CLABSI rates in 2018, the hospital phased out the use of CHG impregnated gel dressings from the CL maintenance bundle. Instead, a discoid shaped dressing made of a sterile polyurethane foam impregnated with CHG, known as the BioPatch, was introduced in its place (Ethicon, 2019). This dressing was applied to the CL insertion site prior, and in addition to, the application of a sterile transparent IV dressing. Despite numerous educational events on the BioPatch, including proper application techniques, in-person training, and real time instruction with feedback during device audits, staff compliance remained low and CLABSI SIR values continued to exceed the NHSN threshold and hospital SIR goal. This prompted the CLABSI team to phase out the BioPatch and reintroduce 3M Tegaderm CHG impregnated gel dressings in accordance with the latest EB CDC guidelines as part of the practice change intervention that was set to launch March 1st 2020 (3M, 2022; CDC, 2017). According to the CDC (2017a), high quality evidence suggests the use of CHG impregnated dressings significantly reduce the incidence of CLABSIs without regard to dressing type, i.e., foam versus gel. Since the hospital achieved a lower incidence of CLABSIs, and greater nursing staff adherence, with the CHG gel dressing, it was decided that its reintroduction was the best course of action.

Condition of dressing and tubing set change. The hospital utilized Paragon Clinical CareStation, an electronic health record, for patient charting, including the documentation of completed CL infection prevention tasks under the CLABSI tab (Allscripts Healthcare, 2022). Upon an extensive patient chart review, the CLABSI team noted the program did not include all fields necessary for proper documentation. The nursing staff were able to check the appropriate box to indicate that the dressing change date was not overdue. However, there were no fields to indicate if the dressing was clean, dry, or intact. Nor was there a field to document whether the IV tubing was overdue to be changed. These items are included in CL maintenance care per the CDC (CDC, 2015) CLABSI prevention guidelines. These guidelines are backed by the latest scientific evidence that demonstrates the CL maintenance interventions are more effective when used together as a bundle, rather than individually (Barnes et al., 2015). Furthermore, research shows a statistically significant association between excellent bundle compliance (>95%) with all CL bundle components and CLABSI reduction

(Furuya et al., 2016). These interventions were included in the CLAPPT to ensure they were not overlooked and to reinforce compliance with the CDC guidelines (CDC, 2015).

Patient education. The patient chart review also revealed a lack of timeliness regarding the task “Patient and/or family received Central Line Associated Bloodstream Infection (CLABSI) prevention education.” Patient CLABSI prevention education is supposed to take place prior to CL placement, or as soon as possible after placement (CDC, 2014). The CLABSI team discovered the education was often provided days to weeks after CL insertion. Documentation for this item was located in Paragon Clinical CareStation; however, CLABSI prevention education handouts for patients were located in another program integrated with the hospital’s EMR called CareNotes, IBM Watson Health, which may have further contributed to noncompliance with the intervention (IBM Watson Health, 2018).

All TJC accredited hospitals in the United States are required to provide CLABSI prevention education to every patient with a CL (Zellmer, Zimdars, & Safdar, 2016). Recent research suggests that involving patients in their own CL care, through increased awareness and knowledge of CLABSIs, is essential to prevent the occurrence of these deadly infections (Zellmer et al., 2016). The immediacy with which the education is provided largely impacts patient outcomes. The CLABSI team added patient education to the CLAPPT with the clarification "prior to CL placement or ASAP after line placement,” as well as the location of the education, to both create a sense of urgency and promote compliance with the interventions.

The CLABSI prevention patient education is based on current CDC recommendations (CDC, n.d.-e). The same information is available from the CDC website and can be found in Appendix C. Included in the handout is a description of CLABSI and CVCs, causes and symptoms of CLABSI, current approaches used by hospital staff and patients to prevent CLABSIs, and post-discharge care instructions (CDC, n.d.-e).

Alcohol port protectors. As previously mentioned, alcohol port protectors (APPs) are listed as a special approach that should be considered when CLABSIs persist despite the employment of CL insertion and maintenance measures (CDC, n.d.-c; Septimus & Moody, 2016). Curos caps, or APPs, are threaded plastic devices impregnated with 70% isopropyl alcohol that twist onto the needleless ports of central and peripheral lines and IV tubing (Merrill et al., 2014). The caps disinfect the port within three minutes and last for seven days, if they remain in place (Merrill et al., 2014). Research shows a statistically significant correlation between Curos caps use and CLABSI reduction (Merrill et al., 2014). Research findings also suggest their use results in significant savings in healthcare costs and decreases hospital length of stay (Merrill et al., 2014). The hospital had already incorporated Curos caps into the routine care of CLs in the ICU and IMCU. In accordance with the latest CDC guidelines and CLABSI prevention literature, the CLABSI team added the intervention to the CLAPPT and implemented it as part of routine CL care hospital-wide (CDC, 2014; Merrill et al., 2014).

Remaining CLAPPT interventions. The remaining CLAPPT interventions were current with the latest CDC recommendations for CL maintenance care (CDC, 2015). They were carried over from the hospital EMR and included in the CLAPPT as part of the bundle approach.

Data Collection

After the development of the CLAPPT tool, a plan for data collection through CVC device audits was established. The plan permitted time for baseline data collection prior to the implementation of CLAPPT, as well as subsequent progress monitoring. The CLABSI team then prepared for a mandatory hospital-wide HP event to educate and train nursing staff regarding the interventions, which were set to rollout March 1, 2020.

Staff Education

HP was a mandatory hospital-wide educational event for nursing staff that took place over three days in February of 2020. HP focused on education and training regarding the updated CLABSI prevention protocols included in the CLAPPT. Education and hands-on training were provided to all nursing staff, including RNs, LPNs, and CAs. In addition to CLABSI, other common harms were part of the HP event, including falls, CAUTI, SSI, Clostridium difficile, sepsis, and venous thromboembolism. Given the current situation, donning and doffing of personal protective equipment for COVID mitigation was also included. The nursing staff had the option of attending HP on three separate dates between February 25th and February 27th from 7 a.m. to 7 p.m.

Separate educational stations were created for each harm. CLABSI education was provided to nursing staff in small groups of six through educational poster boards and handouts, 15-minute verbal presentations, and demonstrations of CHG impregnated CL dressing changes on mannequins. Education focused on all previously mentioned interventions included in the CLAPPT, as well as background and significance of CLABSI, with a highlight on prevention. Nursing staff were also required to complete a return demonstration of a CL dressing change.

The poster boards and handouts also contained tables outlining baseline data related to CLABSI rates and compliance with CLABSI prevention interventions. The data were presented in tables by unit, as well as in a summary table of all units combined. The use of the CLAPPT and the process of device rounds were explained to the staff so they were made aware of how staff compliance with the interventions would be monitored. Afterwards, the nursing staff took a 10-question quiz to assess the effectiveness of the education.

All education and training were provided by the author along with a trained Clinical Educator. Additionally, the poster boards and CLABSI quiz were created by the author. The CLABSI quiz, posterboards, and educational handouts are located in Appendices D through F, respectively.

Device Rounds

Device rounds were completed by the hospital's IP or one other trained auditor during the pre- to early pandemic period, between January 2019 and March 2020, and by each unit's charge nurse during the pandemic from March 2020 to April of 2021. The audits were performed on every patient in the designated units who had an indwelling CVC during the study period. The audits included evaluation of nursing staff compliance with EMR documentation of select CL interventions, as well as direct observation of completion of CL interventions. Audits of EMR documentation were not performed on every CL intervention as it was determined by the IP that in-person audits yielded more reliable data and decreased self-reporting bias.

CVC Device audits, or device days, were conducted with regularity between January 1, 2019, and April 30, 2021. Every patient with a CL in the ICU or IMCU was rounded on every Monday, Wednesday, and Friday. Those with a CL in the medical, cardiac, surgical, neurological, orthopedic, and physical rehabilitation units were rounded on every Tuesday and Thursday.

The hospital IP developed a standardized paper form titled CVC Device Rounds Audit Tool (Appendix G). It was used to collect CL compliance data on each patient with a CL in place during device rounds. The tool was updated to reflect the revised CL maintenance care interventions that were included in the CLAPPT. This version of the tool had not been used previously, and therefore had not yet undergone reliability or validity testing. The form contained places to document the patient's last name, account number, permission to enter (granted or denied), and reason given if access was not permitted.

The audited items were divided into one of two sections within the rounding tool. The first section, CVC Documentation, pertained to the auditing of nursing staff EMR documentation of select CL interventions. Assessment of interventions in the second section, CVC Assessment Audit, was performed under direct observation.

Section one assessed EMR documentation of the following:

1. CVC indication
2. CVC still needed
3. CVC assessed each shift
4. Lines flushed every 8 hours
5. CHG bath in last 24 hours
6. CLABSI Education given

Section two assessed compliance with the following interventions:

1. Dressing is clean and dry
2. Dressing border is intact
3. Tegaderm gel pad is correctly placed over CL insertion site
4. Dressing is dated
5. Dressing not overdue
6. Curos cap on all hubs
7. All hubs are clean
8. Tubing is labeled
9. Tubing is not overdue
10. Tubing is not looped

Using the CVC audit tool, compliance was marked as met (yes), not met (no), or not applicable (N/A). When noncompliant CLs were found during audits, the IP, or another auditor used the opportunity to provide staff with real-time education, instruction, and constructive feedback. There were several reasons why compliance would be marked as N/A. For instance, if a CL had been in place for less than 24 hours, nursing staff may not have had time to complete every intervention, such as giving a CHG bath, or labeling all IV tubing. CLABSI prevention education was required prior to or immediately after CL insertion. However, in emergent situations, or if the patient was incapacitated, this was not always feasible. In these situations, incomplete did not equal noncompliant. As such, the item was marked N/A. As previously discussed, there were times when a patient was unable to be present for device rounds. In those instances, the auditor would assess compliance later that same day or the following day. A review of EMR documentation was always completed.

When device rounds were completed each day, the audit forms were collected and brought back to the IP's locked office. The IP would then strip the data of all identifying information and enter it into an excel spreadsheet, where patients were referenced by numeric designation only, on a password protected computer. The information contained in the spreadsheet included the date, unit, and compliance status (yes, no, N/A) for each intervention. The IP would then place the paper copies in a labeled folder in a locked file cabinet in her office.

Retrospective Review of Data

Following IRB approval, the IP agreed to sponsor the author and provide her with the hospital's CLABSI data. This included monthly CLABSI rates, nursing staff compliance data, and CLABSI education quiz results from the HP event. Monthly CLABSI rates during the study period, January 1, 2019, to April 30, 2021, were reviewed. Baseline data prior to the implementation of the nurse-led practice change were obtained from January 1, 2019, to February 28, 2020. Data from the intervention period were obtained from March 1, 2020, to April 30, 2021. Data from the pre implementation period was compared to data from the post implementation period concerning CLABSI rates and nursing staff compliance with the interventions. Data from the HP event were obtained from February 25, 2020, to February 27, 2020, to evaluate the effectiveness of formal education.

Data Analysis

Evaluation of CLABSI was done using a permutation t-test to compare CLABSI rates before and after the implementation of the CLAPPT using MKinfer Inferential Statistics R package software, version 0.6 (Appendix H). Nurse compliance was analyzed by comparing rates of specific rounds data over time. Due to the unprecedented and unforeseen challenges presented by the COVID-19 pandemic, analysis of nurse compliance beyond simple summaries could not be performed. As such, both numerical and graphical summaries of compliance percentages for the pre- and post-implementation periods and the differences between them were examined. All electronic CLABSI data was deidentified and sent from the IP to the author via encrypted email. The information is being stored on an encrypted USB drive. After seven years, all electronic research files will be destroyed. More discussion on the analytical approaches, as well as the impact of the COVID-19 pandemic on this research, will be provided in the next section.

Chapter Four

The purpose of this study was to determine if a nurse-led collaborative that focused on CLABSI reduction using EB prevention strategies, with an emphasis on maintenance bundles, in the form of a CLAPPT, was successful in decreasing CLABSIs at a rural Midwestern hospital. Nurse compliance with the CLAPPT following formal education was also explored. Statistical analyses were performed to evaluate CLABSI rates and nurse compliance before and after the introduction of the CLAPPT between January 19, 2019, and April 30, 2021. This research poses the following questions:

1) Did CLABSI rates decrease after the implementation of the CLAPPT?
2) Did nursing staff compliance, as observed in the rounds data, change over time?
3) What was the effectiveness of the formal nursing education?

Like previous research on CLABSI prevention (Dumyati et al., 2014; Guerin et al., 2010), this DNP project seeks to provide further information on the effectiveness of CL maintenance bundles on CLABSI rates in both ICU and general ward populations and add to hospital data through the identification of effective CLABSI prevention efforts.

Sample Demographics

This research utilized patients at a 307-bed specialty care hospital. This facility was a verified Level 2 Trauma Center located in the rural Midwestern United States. Deidentified data was used for the purposes of this research. Therefore, it was stripped of any information attached to specific patient demographics. What is known, is that these patients had a CVC in place and were inpatients in one of the designated units during the study period. CLABSI rates were calculated using the number of LCBIs per 1,000 CL days instead of the patient total. Therefore, the patient sample was converted to 12,962

CL days for meaningful use. A total of 8,818 direct patient and electronic medical record (EMR) observations were made for the purposes of this research, all of which were included in this study.

It is unlikely that pediatric patients (under 18 years of age) were included in this study. This hospital did not specialize in pediatric care, and therefore had a limited number of rooms designated for this patient population in one of the adult inpatient units. Furthermore, high acuity patients were admitted through the hospital's emergency department (ED), where they were required to go through an intake huddle process. In most instances, a pediatric patient requiring a CL exceeded the capabilities of the hospital. As such, they were diverted to a hospital that specialized in high acuity pediatric care. Given this hospital did not have a designated pediatric unit, or the resources to care for critically ill children, the pediatric population at this facility has been historically low.

Results and Discussion

Permutation *t*-test

A permutation t-test was utilized to analyze the differences in CLABSI rates before and after the implementation of the CLAPPT. Much like a standard *t*-test, it provides a specific probability for observing a difference between two means, and the interpretation of the test and its results are the same. However, there are basic assumptions that need to be met before using a *t*-test, namely normality of data distribution and equality of variance in standard deviation. Based on the boxplot for the CLABSI rates (illustrated in Figure 1), there is evidence of non-normal distributions. Since the normality assumption cannot be met, using a *t*-test would invalidate any inferences made from the test. The permutation *t*-test does not require normality of the data and is the preferred test when analyzing small datasets.

Using the permutation *t*-test, a simulated distribution of *t*-statistics was created from the data set. To create this simulated sampling distribution, the meaning of the null hypothesis was explored. Since the null hypothesis for this project stated that there is no association between the CLABSI rates and implementation of the interventions, then the pre- and post-implementation rates could have been observed as they were, or in any order. Therefore, under the null hypothesis, the order of the observations made in both the pre- and post-intervention periods was treated as random. It was this idea, the re-randomization of data, that was exploited to create the non-parametric permutation *t*-test.

To create the null distribution, the observed rates were shuffled between the pre and post groups to calculate the permuted *t*-statistic. After 10,000 permutations, a sampling distribution was produced to analyze statistical results that assumed that a set of variants had no effect on the outcome. The assumption used was the independence of observations. The normality assumption was no longer applicable, as is the case with nonparametric tests.

CLABSI Rates

The results with the numeric summary for the CLABSI rate data are shown in Table 1. The CLABSI mean for the post-intervention period (March 1, 2020 – April 30, 2021) is lower than the mean for the pre-intervention period (January 1, 2019 – February 28, 2020). Of note, both medians are zero, which indicates that at least half of the monthly rates are zero. This largely explains why normality could not be assumed.

Table 1

CLABSI Rates by Implementation Period

Period	Mean	SD	Median	IQR
Pre	0.99	1.20	0	2.14
Post	0.87	1.28	0	1.91

The distributions of the two groups of CLABSI rates can be seen in Figure 1 with the pre-intervention rates on the left and the post-intervention rates on the right. The thick horizontal line denotes the median for each group, and the boxes represent the interquartile range which signifies the center 50% of the data. There are a few points of discussion regarding Figure 1. First, both groups are right skewed, with the post-intervention group being more heavily skewed. The skewness observed here is the main reason why a permutation version of a *t*-test was utilized, as the distributions of the CLABSI rates by group are not normal. Second, there is a slightly higher variability in the post-intervention group, but this is likely driven by the CLABSI rate over 3.5.

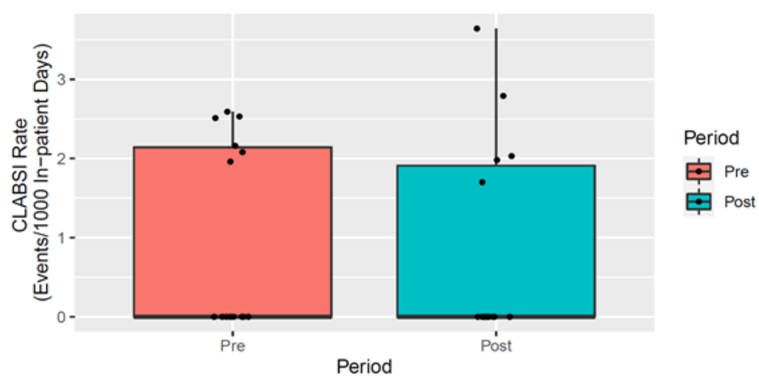

Figure 1. CLABSI Rates by Pre-Post Implementation.

While figure 2 does not factor into the *t*-test, it may be useful in relating rates to the formal nurse education. It is notable that CLABSI rates are zero for the first three months post-implementation (March 2020 - May 2020), when knowledge retention amongst nursing staff was likely high. However, there was no discernable difference in rates or patterns between the pre- and post-intervention periods.

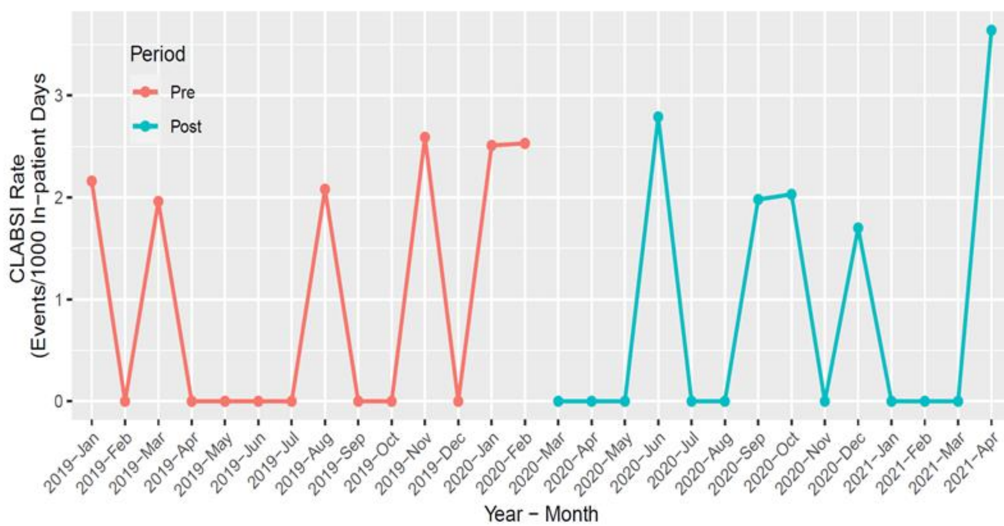

Figure 2. CLABSI Rates by Month and Year.

In comparing the two time periods, the permutation *t*-test was used to determine if the means between the two groups differed, specifically if the pre-intervention group had a larger true mean CLABSI rate than the post group. This formulated the following hypotheses:

- Null hypothesis: There is no difference in mean CLABSI rates before and after implementation of the interventions ($H0 : \mu Pre - \mu Post = 0$).
- Alternate hypothesis: There is a difference in mean CLABSI rates before and after implementation of the interventions ($HA : \mu Pre - \mu Post > 0$).

Again, utilizing a permutation *t*-test precluded reliance upon on any theoretical distributions or real assumptions beyond independence of observations. Of note, there is a potential issue with the fact that these rates are sequential in time, meaning rates from months closer together are likely to be more similar than months further apart. Running the *t*-test with that potential issue in mind, resulted in a *t*-statistic of 0.257, (p = .399). There is a slight decrease in the mean CLABSI rate from 0.99 pre-intervention to 0.87 post-intervention. However, given the relatively large *p*-value, one can conclude there is a lack of evidence to reject the null hypothesis of no difference in CLABSI rates before and after implementation of the CLAPPT. As previously mentioned, this was expected given how close the mean CLABSI values were between the two groups. Based on this test there is insufficient proof to support that the implementation of the CLAPPT was associated with a decrease in CLABSI rates.

Nurse Compliance

Unfortunately, there were several issues with the compliance data that prevented statistical modelling from being performed. First, there were inherent issues with independence of the observations between groups. The rounds database did not track nurses or patients. Therein lies the problem, as there was no way to control for those sources of dependencies in the data. The independence assumption is critical in statistical modelling and cannot be ignored. This issue alone rules out analysis beyond simple summaries. Additionally, compliance modelling requires complete cases in the data. This means that each observation, or row in the database, is without missing values. Owing to incomplete observations, the options for analysis were limited. As such, both numerical and graphical summaries of compliance percentages were used to analyze the differences between the pre- and post-intervention data sets.

Nurse compliance for the pre- and post-intervention periods was determined by calculating the compliance percentage for each of the measures in the rounds database, the summary of which is contained in Table 2. It is of note that the number of total observations differ more than would be expected given the differences in the time lengths for the pre- and post-intervention periods and that some measures do not have a post-intervention period counterpart as they had been phased out with the updating of protocols.

Table 2

Compliance Percentage for Each Measure of the Round Database

Period	Measure	Total	Compliance Count	Compliance Percentage
Pre	tubing_dated	4056	3617	89.18
Post	tubing_dated	812	744	91.63
Pre	set_change_not_overdue	3741	3591	95.99
Post	set_change_not_overdue	707	684	96.75
Pre	no_looping	4080	4006	98.19
Post	no_looping	746	730	97.86
Pre	Lines_flushed	48	33	68.75
Pre	Line_still_needed	6468	6204	95.92
Post	Line_still_needed	1436	1399	97.42
Pre	Edu	1835	1636	89.16
Post	Edu	1315	1143	86.92
Pre	dressingdated	5995	5563	92.79
Post	dressingdated	1334	1294	97.00

Period	Measure	Total	Compliance Count	Compliance Percentage
Pre	dressing_intact	6017	5710	94.90
Post	dressing_intact	1335	1303	97.60
Pre	dressing_clean_dry	6025	5834	96.83
Post	dressing_clean_dry	1333	1308	98.12
Pre	dressing_change_not_overdue	5699	5558	97.53
Post	dressing_change_not_overdue	1301	1281	98.46
Pre	curos_caps_on	5485	4959	90.41
Post	curos_caps_on	1175	1129	96.09
Pre	connectors_are_clean	5389	5330	98.91
Post	connectors_are_clean	1287	1274	98.99
Pre	CLABSI_edu	2436	1966	80.71
Pre	CHG_bath_2	2419	1500	62.01
Pre	CHG_bath	1718	1327	77.24
Post	CHG_bath	1317	1072	81.40
Pre	Blue_CVC_arm_band	434	390	89.86
Pre	BioPatch	747	697	93.31
Pre	assess_Q_shift	2685	2125	79.14
Post	assess_Q_shift	1	1	100.00

To gain a better perspective on the differences between the two time periods, Figure 3 shows the percent compliant for each measure and time period, excluding measures not present in both time periods. Generally, the post-intervention period does have slight increases across the board in compliance percentage with the exception of Education (Edu) and No Looping (no_looping). The largest increase in compliance is seen with Assess Every Shift (assess_Q_shift). However, the post-intervention period only has one observation for this measure. Therefore, no inferences were made based on that singular occurrence.

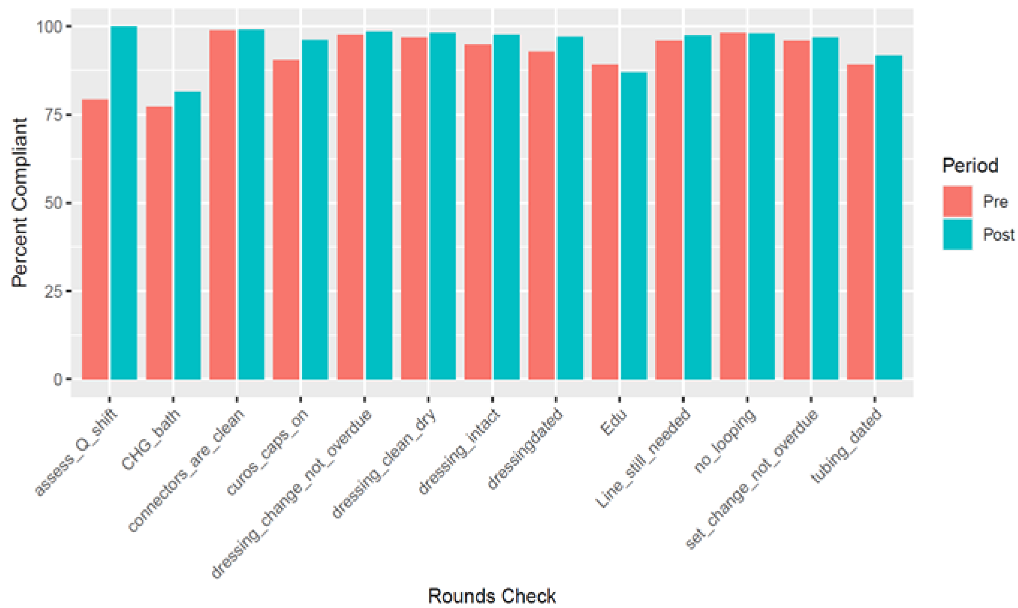

Figure 3. Compliance Rates by Implementation Period.

Finally, in Table 3 is a comparison of the compliance percentages before and after the implementation of the CLAPPT.

Table 3

Compliances Rate Differences by Implementation Period

Measure	Pre	Post	Difference
Edu	89.16	86.92	-2.24
no_looping	98.19	97.86	-0.33
connectors_are_clean	98.91	98.99	0.08
set_change_not_overdue	95.99	96.75	0.76
dressing_change_not_overdue	97.53	98.46	0.93
dressing_clean_dry	96.83	98.12	1.29
Line_still_needed	95.92	97.42	1.50
tubing_dated	89.18	91.63	2.45
dressing_intact	94.90	97.60	2.70
CHG_bath	77.24	81.40	4.16
dressingdated	92.79	97.00	4.21
curos_caps_on	90.41	96.09	5.68
assess_Q_shift	79.14	100.00	20.86

When considering just the measures present in both time periods, a comparison of the compliance percentages between the pre- and post-implementation groups reveals that most differences are less than 5%, with only two measures having decreased compliance percentages in the post time period as pointed out in Figure 3. On average, excluding the assess_Q_shift measure, the average difference in percent compliance is 1.77% and the median difference is 1.39%. Again, while more formal hypothesis testing could not be conducted under these circumstances, there is perceived improvement in overall compliance after implementation of the CLAPPT tool.

Of note, compliance decreased in the post group with regard to the provision of patient education and no looping. Although compliance increased with assess_Q_shift in the post group, this item was only completed once. This indicates that audits of this measure ceased during the post-implementation period. Thus, providing no way to determine how often the assessments were actually performed. Decreased compliance with the aforementioned interventions in conjunction with a possible decrease in frequency of CL assessments may have contributed to the persistence of CLABSIs despite ongoing prevention efforts.

Formal Nursing Education

Considering COVID-19 prevented running a pre-post quiz setup, the quiz results that were obtained are summarized both numerically (illustrated in Table 4) and graphically (illustrated in Figures 4 and 5). A total of 237 RNs, LPNs, and CAs attended HP and participated in the post-test that was designed to determine the effectiveness of the education. The results from all 237 post-tests were included in the study. The mean, standard deviation, and interquartile range of the quiz scores can be seen in Table 4.

Taking both the mean and median, along with their associated measures of spread into consideration, scores were strongly clustered around 100% correct. This is further seen with the quiz results displayed in Figures 4 and 5.

Table 4

CLABSI Quiz Score Summaries

Mean	SD	Median	IQR
0.93	0.09	1	0.12

As seen in Figures 4 and 5, most quiz scores were at or above 85%, with only a few falling below 85%. Thus, demonstrating the overall effectiveness of the education. When surveyed, 99.6% of participants found the CLABSI education helpful.

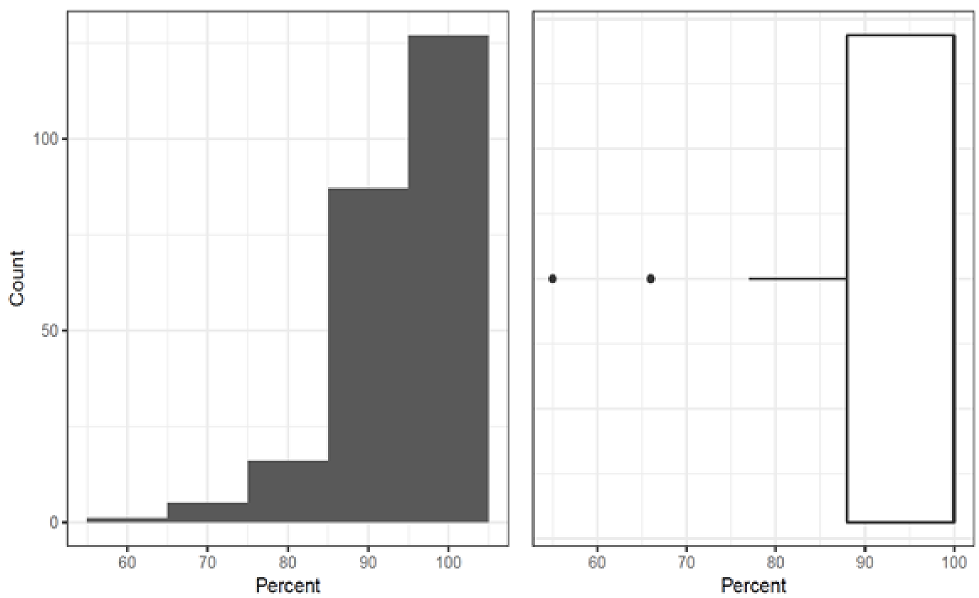

Figure 4. CLABSI Quiz Results. Histogram of Quiz Scores

Figure 5. CLABSI Quiz Results. Boxplot of Quiz Scores

The impact of COVID-19 on this research, CLABSI, and HAI prevention at large, will be discussed further in the following sections.

Impact of the COVID-19 Pandemic

HAI Prevention Efforts

On January 9, 2020, the WHO announced a spate of pneumonia-like cases in Wuhan, China, citing a novel coronavirus as the cause of infection (AJMC Staff, 2021). On January 21, 2020, the CDC confirmed the first case of COVID-19 on U.S. soil, and just ten days later on January 31, 2020, the WHO declared COVID-19 a global health emergency (AJMC Staff, 2021). The pandemic greatly impacted the global healthcare system, and U.S. hospitals were no exception. Given the pervasive and prolonged nature of SARS-CoV-2 transmission, U.S. healthcare facilities experienced an abrupt surge in hospitalizations. This greatly exceeded total hospital capacities nationwide. Hospitals were forced to quickly adapt to manage this sudden influx of patients (Baccolini et al., 2021).

Recent NHSN reports released by the CDC (2021a), revealed a significant uptick in HAIs in 2020 compared to 2019. CLABSI, CAUTI, and ventilator acquired event (VAE) rates increased by 47%, 19%, and 45% across all location types, respectively (CDC, n.d.-d). Higher COVID-19 rates also led to increased device utilization, including CLs, ventilators, and indwelling urinary catheters, and HAI prevention programs suffered as a consequence of the reallocation of resources to focus on COVID-19 mitigation efforts (Baccolini et al., 2021; CDC, n.d.-d). The pandemic response also led to substantial supply shortages of personal protective equipment (PPE), which is vital for HAI management. These issues combined with reduced nurse to patient ratios, longer length of stay, and higher patient acuity may have further increased HAI risk (Baccolini et al., 2021).

CLABSI

Of all the HAIs, new evidence has shown CLABSI has experienced the greatest increase in the wake of the pandemic (CDC, n.d.-d; Fakih et al., 2022; LeRose et al., 2021; McMullen, Smith, & Rebmann, 2020). A study conducted by Fakih et al. (2021), looked at CLABSI and CAUTI outcomes from 78 hospitals within a multi-state healthcare system that were reported to the NSHN. Findings demonstrated a 51% increase in CLABSI rates (0.56 to 0.85 per 1,000 line-days; p<0.001). The most substantial increase occurred in ICUs, where a 71% rise was observed (0.68 to 1.16 per 1,000 line days; $p < 0.001$). This coincides with recent NHSN reports released by the CDC that show a 65% increase in CLABSI rates in U.S. ICUs during 2020 (CDC, n.d.-d).

A similar study conducted by McMullen, Smith, and Rebmann (2020), projected CLABSI would be more severely impacted by the pandemic than other HAIs. As predicted, their research findings demonstrated substantial increases in CLABSI rates at hospitals located in New York City and St. Louis, 420% and 327%, respectively, in comparison to pre-pandemic rates (McMullen et al., 2020).

A third study looked at the impact of the pandemic on CLABSI rates in the greater Detroit area (LeRose et al., 2020). The authors found CLABSIs increased by 325% overall (LeRose et al., 2021). Even after the removal of COVID-19 patients from their analysis, a 194% increase in CLABSI rates remained (LeRose et al., 2021).

Attributable Causes of CLABSI

In this section potential explanations for the increase in CLABSIs during the COVID-19 pandemic will be explored. A review of the current literature revealed the following potential reasons for this uptick in CLABSI rates:

Higher acuity patients. One explanation for this increase in CLABSIs is COVID-19 patients were severely ill, and therefore more susceptible to developing CL infections because they often required a CVC for administration of lifesaving medications and fluids (McMullen et al., 2020). As stated in a study conducted by Fakih et al. (2021), COVID-19 patients were five times more likely to develop CLABSI than non-COVID-19 patients throughout the pandemic.

Length of stay. COVID-19 patients require a longer length of hospital, which puts them at increased risk of developing CLABSI. On average, CLABSI occurred 18 days after a COVID-19 diagnosis (Fakih et al., 2022). Thus, demonstrating the increased infection risk associated with extended hospitalizations.

Prone position. Many COVID-19 patients are placed in the prone position to improve oxygenation. This can result in compromised CL maintenance. A patient in the prone position is more susceptible to pulling, tugging, and friction at CL insertion sites. This position also reduces the visibility of and access to the insertion site for inspection and the provision of maintenance care (McMullen et al., 2020).

Increased device utilization. Critically ill patients are more likely to require a CL than their noncritically ill counterparts. CLs may be in place for weeks or months and are subject to frequent manipulation by various healthcare workers for the purposes of fluid, nutrition, and medication administration, as well as lab draws. Every time a CL is accessed, there is an opportunity for infection (CDC, n.d.-d; McMullen et al., 2020).

Deviation from sterile technique. As previously discussed, COVID-19 patients are more likely to require CLs for the administration of life-sustaining treatment due to a high level of acuity. CLs inserted during emergent situations are less likely to be sterile because the importance of lifesaving medical care supersedes aseptic technique (LeRose et al., 2021).

Femoral access. Practitioners are more likely to choose a femoral vein as an access point in COVID-19 patients. Femoral placement rarely requires ultrasound guidance which decreases insertion time. These expedient variations in insertion practices were made in an effort to decrease COVID-19 exposure. However, CLABSI prevention guidelines strongly discourage the use of femoral veins for CL insertion due to increased risk of infection (LeRose et al., 2021).

Practice changes. To decrease COVID-19 exposure, more patient tasks were clumped, and changes were made in routine care. The changes that disrupted traditional CLABSI prevention efforts included:

1) Relocation of infusion pumps and dialysis equipment into hallways. This increased risk of infection as a result of tubing being on the floor. It also increased the likelihood of pulling, tugging, and friction at the insertion site (Fakih et al., 2022; McMullen et al., 2020).
2) Staff limiting time in patient rooms. This likely reduced compliance with infection prevention practices, such as good hand hygiene, tubing and CL

maintenance, and disinfection of needleless ports prior to vascular access (Fakih et al., 2021; McMullen, Smith, & Rebmann, 2020).

3) Reported increases in vascular access to obtain a blood culture. Increased vascular access leads to increased risk of infection. An increase in rates of blood culture contamination was also reported, which may signify breaches in aseptic technique during lab draws (Fakih et al., 2021).
4) Broad spectrum antibiotic use increased during the pandemic. The combination of the overuse of antibiotics and prolonged use of CLs resulted in an increase in colonization of Candida species associated with CL infections (Fakih et al., 2021).
5) Decreased universal decolonization. Decolonization practices with nasal spray and CHG bathing solutions were performed less frequently due to clumping of patient care and decreased time spent in patient rooms (Fakih et al., 2022).

Staffing issues. Patient surges and increases in patient acuity led to increased staffing demands nationwide. There were frequent reports of nursing shortages and staff were often relocated to meet the needs of the patients, regardless of experience level or knowledge of CLs. This could have caused lapses in proper CL care (McMullen et al., 2020).

CL audits. Routine CL audits are necessary to guarantee best practices are being followed to prevent infections. During the pandemic the focus shifted from HAI prevention to COVID-19 mitigation, which greatly disrupted traditional CLABSI prevention efforts, such as performing regularly scheduled CL audits to ensure nurse compliance with maintenance care (Fakih et al., 2022).

CMS waived HAI reporting requirements. The waiving of HAI reporting requirements prevented data submissions from January to June of 2020 from CMS hospital quality incentive programs. This may have unintentionally taken the focus off of CLABSIs, resulting in decreased prioritization and an increase in CL infections (Fakih et al., 2021).

Decreased diagnostic testing. Fewer diagnostic tests were performed on COVID-19 patients when not deemed absolutely necessary. Transporting this patient population throughout the hospital to undergo testing was minimized to reduce COVID-19 exposure. However, certain diagnostics, i.e., imaging, is important in ruling out CLABSI as a secondary disease process (McMullen, Smith, & Rebmann, 2020).

Overall burden of COVID-19. The overall increase in demands placed on the U.S. healthcare system led to a major disruption in routine healthcare practices nationwide, which likely resulted in an increase in CLABSIs (LeRose et al., 2021).

Many lessons can be learned from the data and research that has recently emerged regarding the effects of the COVID-19 pandemic on U.S. healthcare. One unfortunate outcome has been an increase in HAIs, with the largest increase seen among CLABSIs. With a shift in focus to and reprioritization of CLABSI prevention, this knowledge can be applied to help anticipate the challenges posed by the pandemic, or other such global emergencies, and prepare healthcare institutions to overcome these obstacles to decrease CLABSIs and improve patient outcomes.

Clinical Implications

Through extensive literature review this research identified EB practices effective in CLABSI prevention, as well as potential factors that attributed to the rise in CLABSI rates during the pandemic. As such, this project could serve as a roadmap to help develop effective CLABSI prevention and COVID-19 mitigation strategies during the ongoing pandemic and in future healthcare crises.

In addition to raising awareness of increased mortality and healthcare costs associated with CLABSIs, this study supports that a daily checklist may be useful in promoting compliance with CDC recommended CLABSI prevention guidelines. However, further research would be needed in a setting that produced data conducive to statistical modelling to determine significance.

Grounds for Further Research

Although there was a slight decrease in the mean CLABSI rate between the pre-and post-implementation groups, the large *p* value demonstrates there is not enough evidence to reject the null hypothesis. However, CLABSI rates did remain stable despite recent reports from the CDC (2021a) that show an overall increase of 47% in U.S. CLABSI rates during the pandemic. Based on this information, one can infer that the intervention may have been of potential benefit, albeit nonsignificant. This could provide grounds for further research regarding CLABSI prevention utilizing the EB infection prevention strategies and mitigating potential CLABSI risks posed by the pandemic mentioned herein.

Statistical modeling could not be performed to analyze nurse compliance with the interventions. Nonetheless, the data summary did demonstrate an overall increase in compliance with the interventions post-implementation of the CLAPPT. Further research would need to be conducted regarding its use in a more controlled setting where CLABSI prevention and COVID-19 mitigation are mutually prioritized.

One of the greatest deficits in the literature regarding HAI prevention is the study of CLABSI reduction in non-ICU populations. And even less is known about the impact of maintenance care on CLABSI rates across all patient populations. This study could be used as a springboard to guide further research in the implementation of EB practices, with a focus on maintenance bundles, to reduce CLABSI in both ICU and general population wards.

Strengths and Limitations

Strengths

There were several strengths identified throughout this DNP project. To start with, this is one of the few studies to explore CLABSI reduction in both ICU and general patient populations, with an emphasis on maintenance care. It is also one of the first studies to do so in the wake of the pandemic. Furthermore, as a result of this research EB CLABSI prevention strategies and potential causes of the influx in CLABSIs during the pandemic were identified.

The formal education regarding the CLAPPT intervention was delivered to the nursing staff in a consistent manner. Clinical educators trained in CLABSI prevention provided the training utilizing the same educational materials to guide the teaching process and the same post-test to evaluate the effectiveness of the education. HP was a mandatory event for all nursing staff. This provided assurance that the entire staff received this information.

The CLABSI prevention education was incorporated into a mandatory online module with a 10 question post-quiz that was required to be completed upon hire, and yearly thereafter for incumbent employees. This ensured that all new hires, including travel nurses, would receive the education presented at HP and that current employees would receive annual reeducation. Additionally, CL care, maintenance policies, and education were standardized across all units, which ensured that each patient received the same EB care regardless of location within the hospital.

The process of data collection was another strength of the study. Data collection took place in a systematic fashion using a standardized rounding tool on a fixed rotation schedule. Data collected during rounds were entered into an electronic Excel file on a weekly basis. The data were clearly marked and categorized for ease of access regarding retrospective use.

Although a convenience sampling method was utilized, all patients from the designated units with a CL were included in the review of CLABSI rates and staff compliance with the interventions prior to and following the implementation of the CLAPPT. Given the total population was included in this study, results can be generalized to all patients with CLs on similar units throughout this healthcare facility.

Limitations

There were numerous limitations of this research, both inherent and extraneous. To begin, this was a retrospective study that utilized a convenience sampling method. Therefore, the lack of random assignment may have limited the internal validity and the generalizability of the results to larger populations and resulted in conclusions about causality that were less definitive. Furthermore, this study was conducted at a single medical facility, which may have contributed further to decreased generalizability of the research findings.

As previously discussed, statistical analysis of nurse compliance could not be performed beyond basic measures as a result of incomplete data sets and the unmet assumption of independence. Prior to the pandemic, the IP, or one other trained auditor, was responsible for performing the CL audits. During the pandemic period, this responsibility fell onto each unit's charge nurse. Although overall compliance rates increased during the post-implementation period, device rounds were no longer performed by one of the two trained auditors. Instead, this task was completed by an alternating pool of nurses acting as auditors, who were not properly trained in device audits or data collection. This may have led to reporting bias regarding the consistency of the audits and the accuracy of data collection. Similarly, all nurses were required to provide EMR documentation of completed CL maintenance tasks, which may have introduced self-reporting bias.

The medical facility had a CL insertion bundle compliance rate of 100%. However, the reporting of compliance data was done by nursing staff who assisted the provider with insertion. This may have introduced reporting bias, and therefore skewed the results. A breach in CL insertion protocol would have put the CL maintenance interventions at a disadvantage from the start as this would have increased the likelihood of infection at the point of insertion.

The device rounds audit tool was newly revised, and therefore had not been subjected to reliability or validity testing. In consideration of the foregoing, the audit tool and its use were explained in detail and a copy was included in Appendix G. Furthermore, completed CLAPPT forms were intended to be tallied monthly to calculate completion rates. However, the restraints levied by the pandemic prevented this from occurring during the course of this study.

This DNP project was initially designed to include running a pre-and post-test setup to evaluate the effectiveness of the formal education. However, the pandemic prevented this opportunity from occurring, as large gatherings were discouraged. Using the test scores that were obtained, the results showed a CLABSI post-test mean of 93%, which demonstrates the immediate effectiveness of the intervention. It is notable that CLABSI rates are zero for the first three months post-implementation, when knowledge retention amongst nursing staff was likely high. Unfortunately, further testing could not be conducted to confirm the retention rate several months out.

It is also worth mentioning the majority of the negative pressure rooms at this facility are located in the ICU. This is where most of the COVID-19 patients were housed, regardless of ICU status. The number of expected CLABSIs is based on each unit's patient mix. As the number of non-ICU COVID-19 patients increased, the unit lost its official ICU status. This dramatically lowered the number of expected CLABSIs, and in turn, increased the hospital's CLABSI SIR value.

Further limitations of this research can be attributed to the consequences of the pandemic as outlined previously. As such, traditional CLABSI prevention measures were greatly affected, resulting in lapses in CL maintenance care and incomplete and inconsistent reporting and data collection. This likely attributed to persistent CLABSI rates despite ongoing CLABSI prevention efforts.

Conclusion

CLABSIs are the number one cause of HAIs, despite being a preventable harm. They are associated with increased mortality, healthcare costs, and prolonged hospital stays. EB guidelines suggest that CL bundles are the most effective way to reduce CLABSIs. However, most CLABSI prevention research has focused on CL insertion bundles in ICU patient populations. There is a massive deficit in the literature regarding CLABSI prevention outside of ICUs, and an even greater deficit regarding the effectiveness of maintenance bundles across all patient populations.

This DNP project utilized a retrospective pretest-posttest design to explore the effectiveness of a CLAPPT, with a focus on preventative maintenance care, in reducing CLABSIs at a rural Midwestern hospital. Nurse compliance with the interventions following formal education was also explored.

In the 14 months following the implementation of the CLAPPT, CLABSI rates decreased slightly from a mean of 0.99 to 0.87 per 1,000 CL days ($p = .399$). Given the large p-value, there was insufficient evidence to reject the null hypothesis of no difference in CLABSI rates before and after implementation of the CLAPPT. Furthermore, statistical modelling could not be performed for review of nurse compliance with the interventions. Using both numerical and graphical summaries of compliance percentages for each of the two time periods and the differences between them, there was a perceived overall increase in nurse compliance with the interventions. Most differences were less than 5%, with only two measures decreasing in compliance percentages in the post implementation period. Again, while more formal hypothesis testing could not be conducted, there does seem to be an overall improvement in compliance after implementation of the CLAPPT tool. CLABSI post-test scores were strongly clustered around 100% correct, with a mean of 0.93 and a median of 1.0, demonstrating the effectiveness of the formal education.

This study added to the body of nursing knowledge by being one of the few to measure the effectiveness of CL maintenance bundles in both ICU and non-ICU populations, while exploring factors of compliance. This was also one of the first studies to do so during the pandemic. Furthermore, this study provides a platform for advanced practice nurses to conduct further research to produce EB data that will help shape policies that identify and guide best practices in CLABSI prevention, and by this means, positively influence patient outcomes. Additionally, through this research both EB CLABSI prevention measures and potential attributable causes of increased CL infections as a result of the pandemic were identified. Unfortunately, this DNP project was subjected to the unforeseen consequences of the pandemic, and therefore did not realize its full potential. Future research exploring the effectiveness of CL maintenance care in CLABSI reduction in a variety of populations and settings is recommended. Further emphasis should be placed on protecting against potential causes of increased infections consequent to the pandemic and in anticipation of other such global health emergencies.

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Appendix A

University IRB Approval Document

Office of Graduate Education and Research
401 Cohodas Hall
Marquette, MI 49855-5301
906-227-2300
www.nmu.edu/graduatestudies

Memorandum

TO: Kristi Robinia
Crystal LaValley
Nursing Department

FROM: Derek Anderson
NMU IRB Chair

DATE: May 25, 2022

SUBJECT: IRB Review for "Reducing Central Line Associated Bloodstream Infections (CLABSI) at a Rural Midwestern Hospital Through an Evidence-Based Nurse-Led Practice Change Intervention"

The Northern Michigan University Institutional Review Board Chair has reviewed your study and deemed that it does not require IRB review.

If the role of human subjects in your study changes in the future, you must submit the changes to the IRB for review.

Appendix B

Central Line Adult Point Prevalence Tool (CLAPPT)

Central line point prevalence

Unit:
Date:

Place patient sticker here

	Shift: Reviewer:	Shift: Reviewer:	Shift: Reviewer:
Point Prevalence	*Circle One*	*Circle One*	*Circle One*
Dressing clean, dry and intact	Yes No	Yes No	Yes No
Dressing dated	Yes No	Yes No	Yes No
CHG gel pad is placed with contact to skin around **entire central line insertion site**	Yes No n/a	Yes No n/a	Yes No n/a
Transparent dressing changed when wet, soiled, or loose and within 7 days; gauze dressing changed when wet, soiled, or loose and within 2 days	Yes No n/a	Yes No n/a	Yes No n/a
IV tubing is dated with time when it is hung	Yes No n/a	Yes No n/a	Yes No n/a
IV tubing is not overdue for change 96 hours if continuous fluids 24 hours if disconnected/intermittent 24 hours if TPN 12 hours if lipids/propofol 4 hours if blood	Yes No n/a	Yes No n/a	Yes No n/a
Alcohol port protectors (Curos caps) are placed on **all injection ports** of the central line and the central line tubing	Yes No n/a	Yes No n/a	Yes No n/a
Daily evaluation of clinical necessity of central line is completed with prompt removal of any line determined to be unnecessary	Yes No	Yes No	Yes No
Has the patient and/or family received Central Line Associated Bloodstream Infection (CLABSI) prevention education in CareNotes? Please note: this should be done before line placement or ASAP after line placement. This is separate from DC education.	Yes No	Yes No	Yes No
Patient received **CHG bath** in last 24 hours and documentation reflects this.	Yes No n/a	Yes No n/a	Yes No n/a

Provide immediate follow up with patient's nurse about any "Nos" on this review

Comments:

Not a part of the permanent medical record

Unit manager to share results with staff during unit huddles

Ver. 9 5/25/17 A. Kilroy

Appendix C

The CLABSI Prevention Patient Education Handout

FAQs
(frequently asked questions)

about

"Catheter-Associated Bloodstream Infections"

(also known as "Central Line-Associated Bloodstream Infections")

What is a catheter-associated bloodstream infection?

A "central line" or "central catheter" is a tube that is placed into a patient's large vein, usually in the neck, chest, arm, or groin. The catheter is often used to draw blood, or give fluids or medications. It may be left in place for several weeks. A bloodstream infection can occur when bacteria or other germs travel down a "central line" and enter the blood. If you develop a catheter-associated bloodstream infection you may become ill with fevers and chills or the skin around the catheter may become sore and red.

Can a catheter-related bloodstream infection be treated?

A catheter-associated bloodstream infection is serious, but often can be successfully treated with antibiotics. The catheter might need to be removed if you develop an infection.

What are some of the things that hospitals are doing to prevent catheter-associated bloodstream infections?

To prevent catheter-associated bloodstream infections doctors and nurses will:

- Choose a vein where the catheter can be safely inserted and where the risk for infection is small.
- Clean their hands with soap and water or an alcohol-based hand rub before putting in the catheter.
- Wear a mask, cap, sterile gown, and sterile gloves when putting in the catheter to keep it sterile. The patient will be covered with a sterile sheet.
- Clean the patient's skin with an antiseptic cleanser before putting in the catheter.
- Clean their hands, wear gloves, and clean the catheter opening with an antiseptic solution before using the catheter to draw blood or give medications. Healthcare providers also clean their hands and wear gloves when changing the bandage that covers the area where the catheter enters the skin.
- Decide every day if the patient still needs to have the catheter. The catheter will be removed as soon as it is no longer needed.
- Carefully handle medications and fluids that are given through the catheter.

What can I do to help prevent a catheter-associated bloodstream infection?

- Ask your doctors and nurses to explain why you need the catheter and how long you will have it.
- Ask your doctors and nurses if they will be using all of the prevention methods discussed above.
- Make sure that all doctors and nurses caring for you clean their hands with soap and water or an alcohol-based hand rub before and after caring for you.

If you do not see your providers clean their hands, please ask them to do so.

- If the bandage comes off or becomes wet or dirty, tell your nurse or doctor immediately.
- Inform your nurse or doctor if the area around your catheter is sore or red.
- Do not let family and friends who visit touch the catheter or the tubing.
- Make sure family and friends clean their hands with soap and water or an alcohol-based hand rub before and after visiting you.

What do I need to do when I go home from the hospital?

Some patients are sent home from the hospital with a catheter in order to continue their treatment. If you go home with a catheter, your doctors and nurses will explain everything you need to know about taking care of your catheter.

- Make sure you understand how to care for the catheter before leaving the hospital. For example, ask for instructions on showering or bathing with the catheter and how to change the catheter dressing.
- Make sure you know who to contact if you have questions or problems after you get home.
- Make sure you wash your hands with soap and water or an alcohol-based hand rub before handling your catheter.
- Watch for the signs and symptoms of catheter-associated bloodstream infection, such as soreness or redness at the catheter site or fever, and call your healthcare provider immediately if any occur.

If you have additional questions, please ask your doctor or nurse.

Co-sponsored by:

SHEA The Society for Healthcare Epidemiology of America; IDSA; American Hospital Association; APIC Spreading knowledge. Preventing infection.; CDC Centers for Disease Control and Prevention; The Joint Commission

Appendix D

CLABSI quiz

CLABSI HARMS PREVENTION

The results of this quiz may be used in future research
All participants will remain anonymous

1. **Transparent dressings are to be changed**
- (•) Every 7 days, or when wet, loose or soiled
- ( ) Every 3 days, or when wet, loose or soiled
- ( ) Every 7 days and reinforce dressing with tape if loose from dirt or moisture

2. **Alcohol port protectors (Curos caps) are placed on all injection ports of the central line and the central line tubing**
- (•) True
- ( ) False

3. **Patient and/or family should receive (CLABSI) prevention education**
- (•) Before line placement or ASAP after line placement.
- ( ) At discharge
- ( ) When the central line is discontinued

4. **Patients with central lines should receive a CHG bath**
- (•) Every 24 hours
- ( ) Every 12 hours
- ( ) At the start of each shift

5. **Evaluation of clinical necessity of central line is completed**
- (•) Daily
- ( ) Every 3 days
- ( ) Weekly

6. **Gauze dressing changes are required**
- ( ) Every 24 hours, or when loose, wet or soiled
- (•) Every 48 hours, or when loose, wet or soiled
- ( ) Every 7 days, or when loose, wet or soiled.

7. **IV tubing changes are required for lipids and lipid-based drips such as Propofol**

- ○ Every 12 hours
- ○ Every 6 hours
- ◉ Every 24 hours

8. **Central line lab draws now require a physician's order**

- ◉ True
- ○ False

9. **CHG gel pad is placed with contact to skin around entire central line insertion site**

- ◉ True
- ○ False

10. **Do you feel this educational session better prepared you to care for patients with central line placement?**

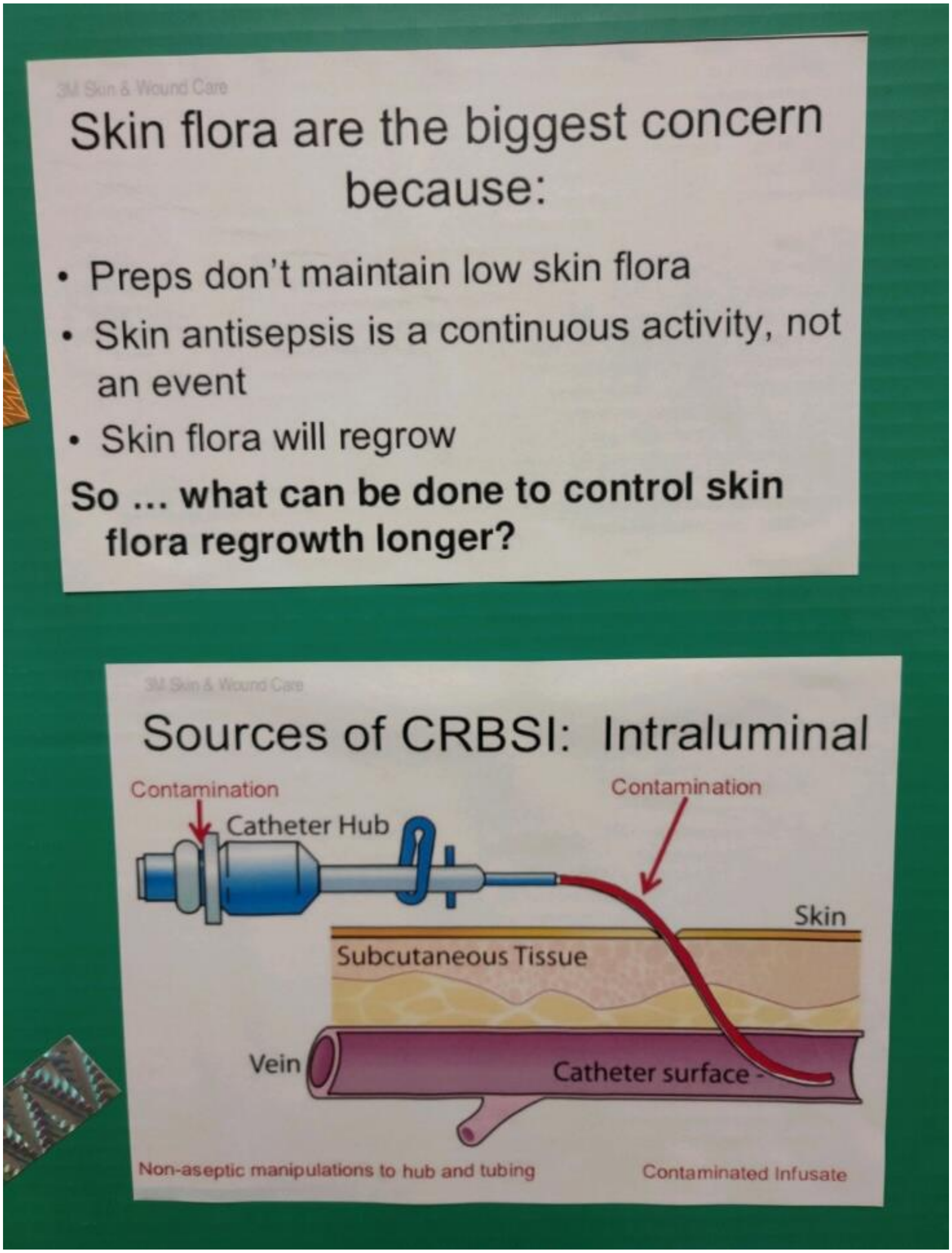
- ○ Yes
- ○ No

Appendix E

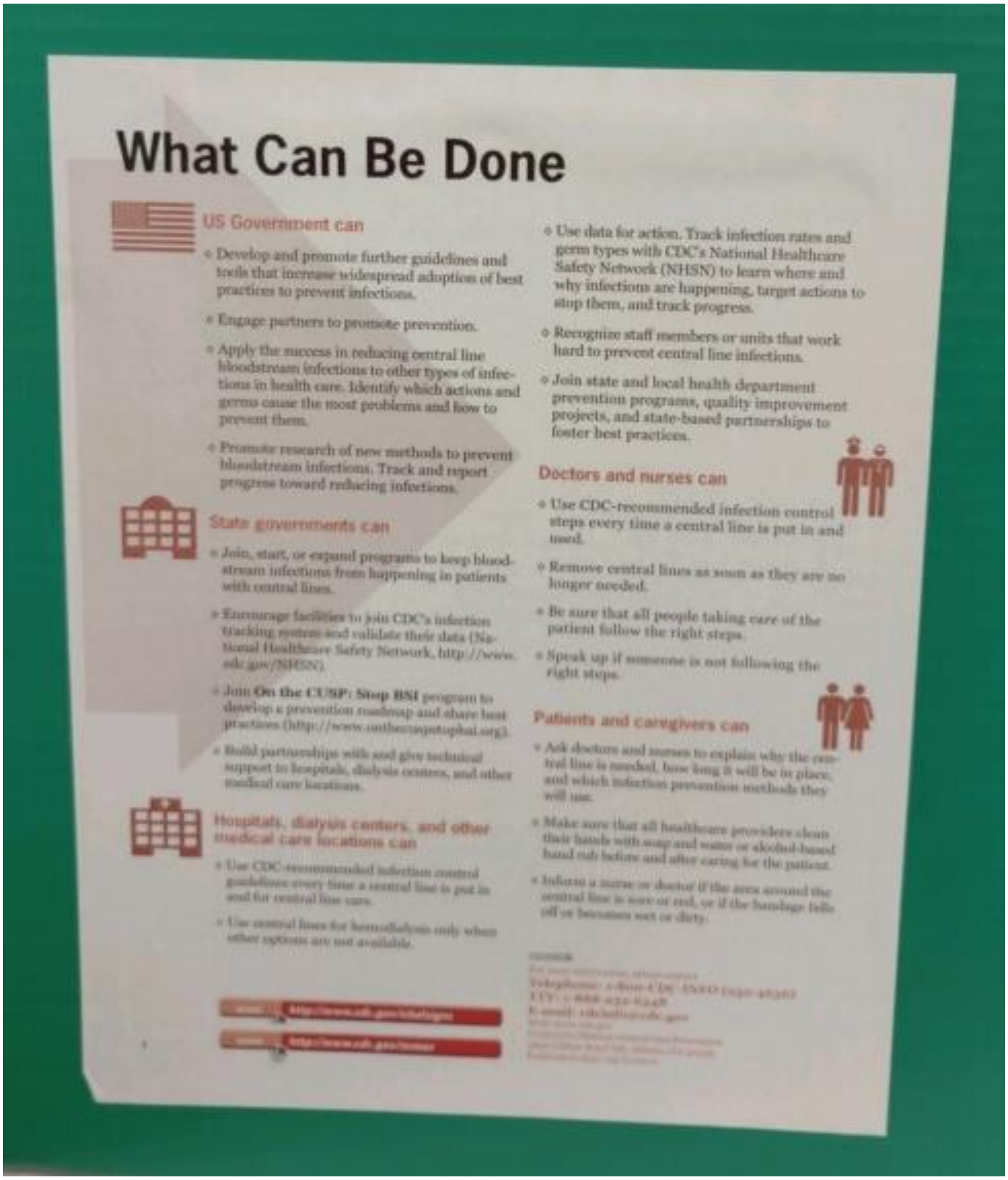
CLABSI Educational Posterboard

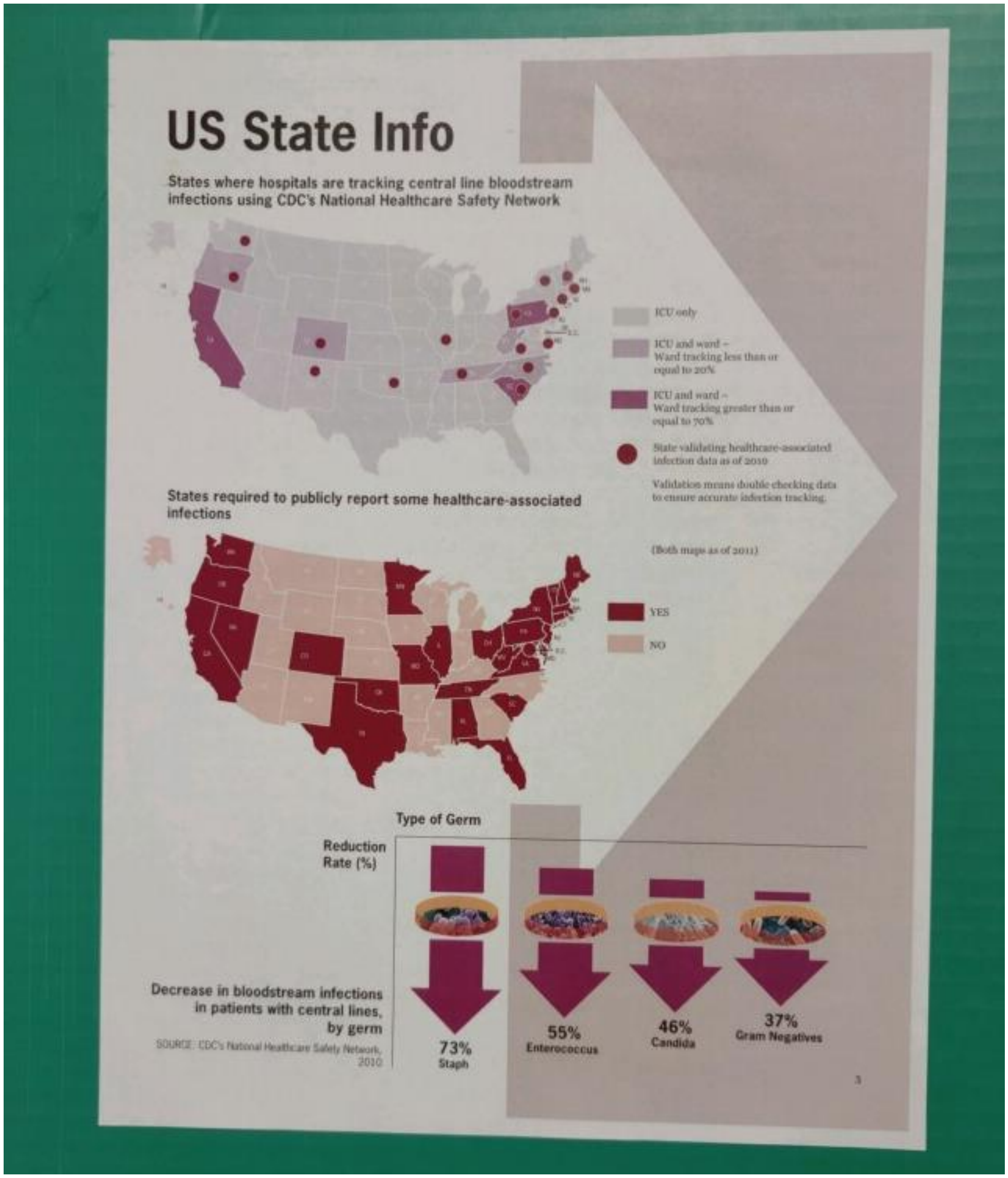
Appendix F

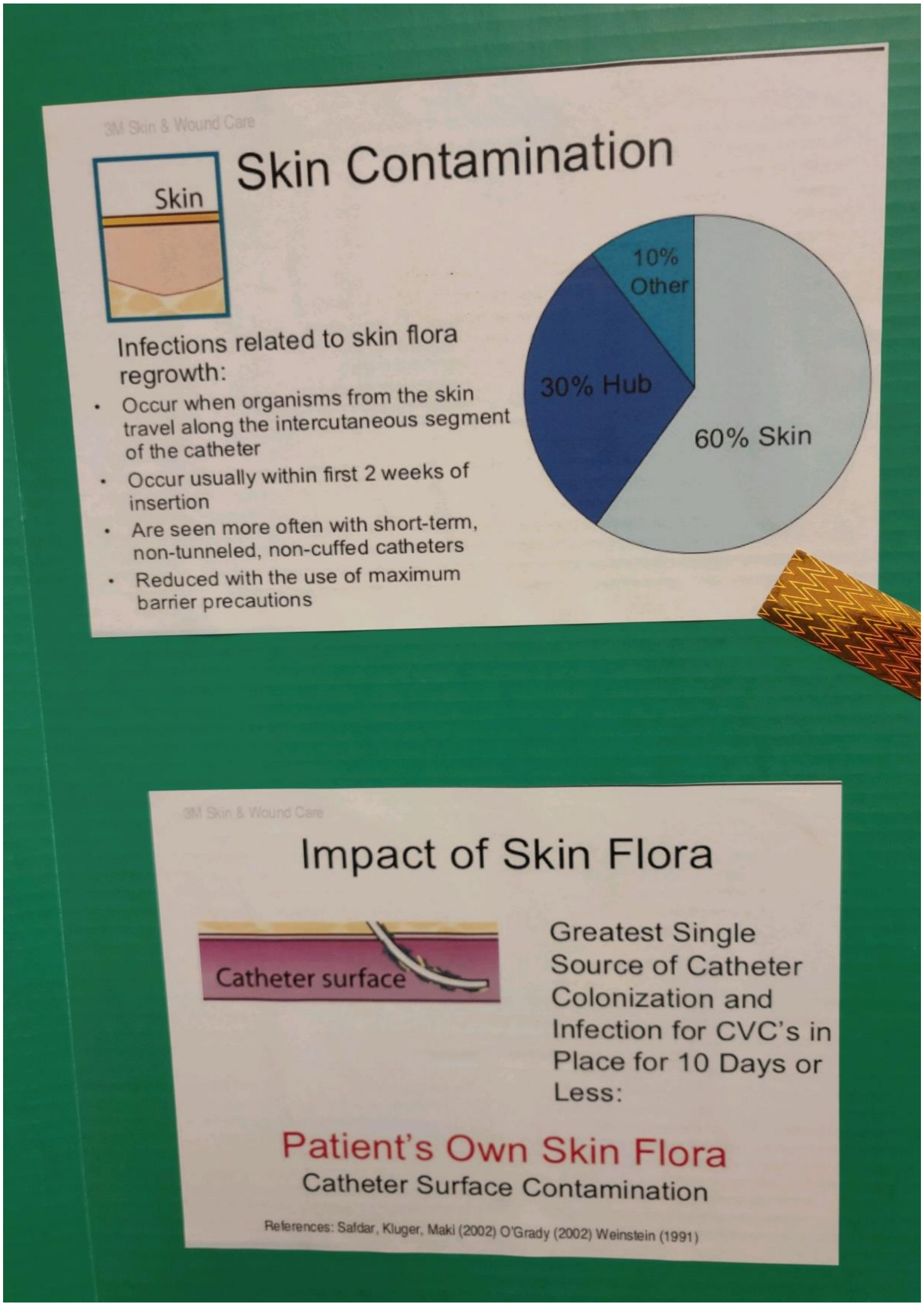
CLABSI Posterboard of Educational Materials with Handout Information

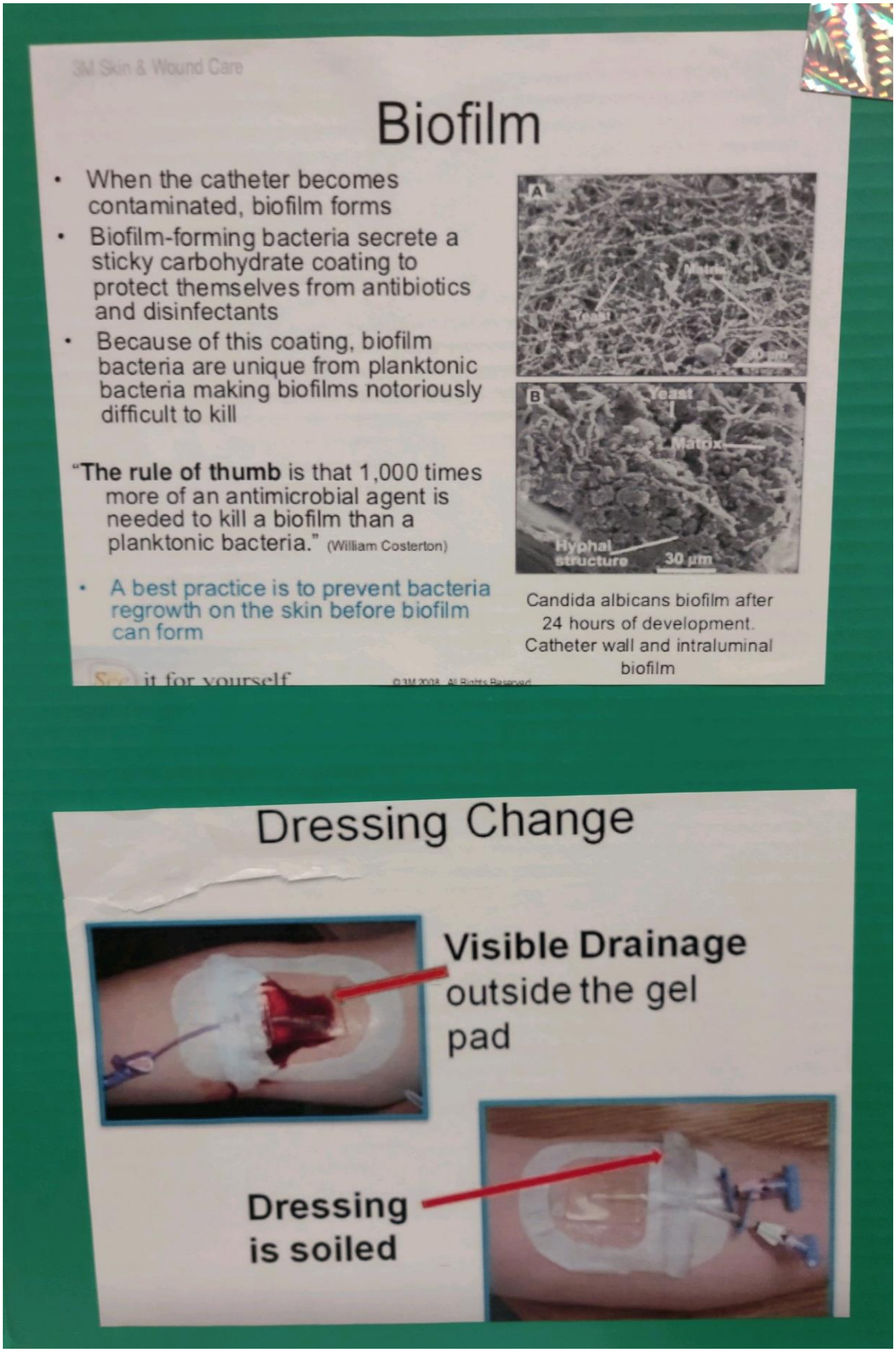


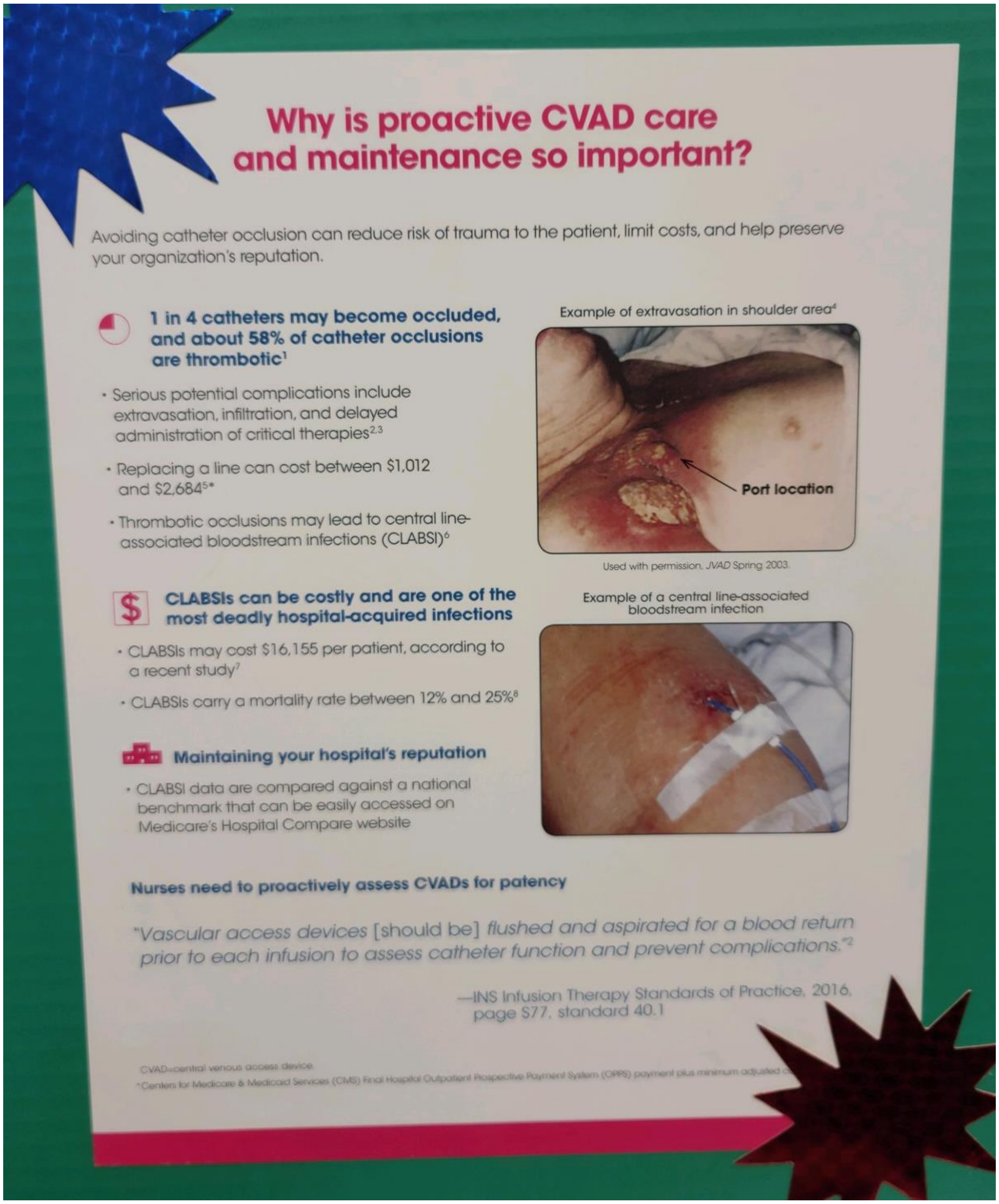

CDC Vitalsigns™
March 2011
Making Health Care Safer
Reducing bloodstream infections
1 in 20
About 1 in 20 patients gets an infection each year while receiving medical care.
41,000
About 41,000 bloodstream infections strike hospital patients with central lines each year.
37,000
About 37,000 bloodstream infections happen each year to kidney dialysis patients with central lines.
A central line is a tube that a doctor usually places in a large vein of a patient's neck or chest to give important medical treatment. When not put in correctly or kept clean, central lines can become a freeway for germs to enter the body and cause serious bloodstream infections. These infections can be deadly. Of patients who get a bloodstream infection from having a central line, up to 1 in 4 die. Bloodstream infections in patients with central lines are largely preventable when healthcare providers use CDC-recommended infection control steps. Medical professionals have reduced these infections in hospital intensive care unit (ICU) patients by 58% since 2001. Even so, many still occur in ICUs, in other parts of hospitals, and in outpatient care locations. In 2008, about 37,000 bloodstream infections occurred in hemodialysis* outpatients with central lines.
Learn what you can do to reduce central line bloodstream infections.
→ See page 4
Want to learn more? Visit
http://www.cdc.gov/vitalsigns
National Center for Emerging and Zoonotic Infectious Diseases
CDC


What Can Be Done
US Government can
Develop and promote further guidelines and tools that increase widespread adoption of best practices to prevent infections.
Engage partners to promote prevention.
Apply the success in reducing central line bloodstream infections to other types of infections in health care. Identify which actions and germs cause the most problems and how to prevent them.
Promote research of new methods to prevent bloodstream infections. Track and report progress toward reducing infections.
State governments can
Join, start, or expand programs to keep bloodstream infections from happening in patients with central lines.
Hospitals, dialysis centers, and other medical care locations can
Use data for action. Track infection rates and germ types with CDC's National Healthcare Safety Network (NHSN) to learn where and why infections are happening, target actions to stop them, and track progress.
Recognize staff members or units that work hard to prevent central line infections.
Join state and local health department prevention programs, quality improvement projects, and state-based partnerships to foster best practices.
Doctors and nurses can
Use CDC-recommended infection control steps every time a central line is put in and used.
Remove central lines as soon as they are no longer needed.
Be sure that all people taking care of the patient follow the right steps.
Speak up if someone is not following the right steps.
Patients and caregivers can


US State Info
States where hospitals are tracking central line bloodstream infections using CDC's National Healthcare Safety Network
ICU only
ICU and ward – Ward tracking less than or equal to 20%
ICU and ward – Ward tracking greater than or equal to 70%
State validating healthcare-associated infection data as of 2010
Validation means double checking data to ensure accurate infection tracking.
States required to publicly report some healthcare-associated infections
(Both maps as of 2011)
YES
NO
Type of Germ
Reduction Rate (%)
Decrease in bloodstream infections in patients with central lines, by germ
SOURCE: CDC's National Healthcare Safety Network, 2010
73%
Staph
55%
Enterococcus
46%
Candida
37%
Gram Negatives


3M Skin & Wound Care
Skin Contamination
Skin
Infections related to skin flora regrowth:
• Occur when organisms from the skin travel along the intercutaneous segment of the catheter
• Occur usually within first 2 weeks of insertion
• Are seen more often with short-term, non-tunneled, non-cuffed catheters
• Reduced with the use of maximum barrier precautions
10% Other
30% Hub
60% Skin
3M Skin & Wound Care
Impact of Skin Flora
Catheter surface
Greatest Single Source of Catheter Colonization and Infection for CVC's in Place for 10 Days or Less:
Patient's Own Skin Flora
Catheter Surface Contamination
References: Safdar, Kluger, Maki (2002) O'Grady (2002) Weinstein (1991)


3M Skin & Wound Care
Biofilm
• When the catheter becomes contaminated, biofilm forms
• Biofilm-forming bacteria secrete a sticky carbohydrate coating to protect themselves from antibiotics and disinfectants
• Because of this coating, biofilm bacteria are unique from planktonic bacteria making biofilms notoriously difficult to kill
"The rule of thumb is that 1,000 times more of an antimicrobial agent is needed to kill a biofilm than a planktonic bacteria." (William Costerton)
• A best practice is to prevent bacteria regrowth on the skin before biofilm can form
A
B
Yeast
Matrix
Hyphal structure
30 µm
Candida albicans biofilm after 24 hours of development. Catheter wall and intraluminal biofilm
Dressing Change
Visible Drainage outside the gel pad
Dressing is soiled


Why is proactive CVAD care and maintenance so important?
Avoiding catheter occlusion can reduce risk of trauma to the patient, limit costs, and help preserve your organization's reputation.
1 in 4 catheters may become occluded, and about 58% of catheter occlusions are thrombotic1
• Serious potential complications include extravasation, infiltration, and delayed administration of critical therapies2,3
• Replacing a line can cost between $1,012 and $2,6845*
• Thrombotic occlusions may lead to central line-associated bloodstream infections (CLABSI)6
Example of extravasation in shoulder area4
Port location
Used with permission, JVAD Spring 2003.
CLABSIs can be costly and are one of the most deadly hospital-acquired infections
• CLABSIs may cost $16,155 per patient, according to a recent study7
• CLABSIs carry a mortality rate between 12% and 25%8
Example of a central line-associated bloodstream infection
Maintaining your hospital's reputation
• CLABSI data are compared against a national benchmark that can be easily accessed on Medicare's Hospital Compare website
Nurses need to proactively assess CVADs for patency
"Vascular access devices [should be] flushed and aspirated for a blood return prior to each infusion to assess catheter function and prevent complications."2
—INS Infusion Therapy Standards of Practice, 2016, page S77, standard 40.1
CVAD=central venous access device.
*Centers for Medicare & Medicaid Services (CMS) Final Hospital Outpatient Prospective Payment System (OPPS) payment plus minimum adjusted

Appendix G

CVC Device Rounds Audit Tool

		CVC Audit															IUC AUDIT							
Central Venous Catheter and Indwelling Urinary Catheter Audit **Date:**		**CVC Location/Type** (includes PICCs, hemodialysis caths, accessed ports)	**CVC Indication**	**CVC appropriate**	Dressing is clean, dry & not bloody to gel	Dressing border is intact	Dressing is dated	Tegaderm date ≤7 days old or gauze ≤2	Curos cap on all hubs	All hubs are clean	Tubing is labeled	Tubing is not overdue	Tubing is not looped	CHG bathing documented in last 24	CLABSI education doc at placement/ASAP	**IUC indication**	**IUC appropriate**	Bag off floor	Bag below bladder	Urine flow unobstructed	Seal intact *CBI, specialty caths, leg bags*	Tubing secured	CAUTI education doc at placement/ASAP after
Room	Acct #			Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a		Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a
Comments:																							
Room	Acct #			Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a		Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a
Comments:																							
Room	Acct #			Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a		Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a
Comments:																							
Room	Acct #			Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a		Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a
Comments:																							
Room	Acct #			Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a		Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a
Comments:																							
Room	Acct #			Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a		Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a
Comments:																							
Room	Acct #			Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a		Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a
Comments:																							
Room	Acct #			Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a		Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a
Comments:																							
Room	Acct #			Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a		Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a
Comments:																							

Central Venous Catheter and Indwelling Urinary Catheter Audit

Date:

		CVC Audit														IUC AUDIT							
		CVC Location/Type (includes PICCs, hemodialysis caths, accessed ports)	**CVC Indication**	**CVC appropriate**	Dressing is clean, dry & not bloody to gel edge	Dressing border is intact	Dressing is dated	Tegaderm date ≤7 days old or gauze ≤2 days old	Curos cap on all hubs	All hubs are clean	Tubing is labeled	Tubing is not overdue	Tubing is not looped	CHG bathing documented in last 24	CLABSI education doc at placement/ASAP after	**IUC indication**	**IUC appropriate**	Bag off floor	Bag below bladder	Urine flow unobstructed	Seal intact *CBI, specialty caths, leg bags = N/A*	Tubing secured	CAUTI education doc at placement/ASAP after
Room	Acct #			Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a		Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a
Comments:																							
Room	Acct #			Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a		Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a
Comments:																							
Room	Acct #			Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a		Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a
Comments:																							
Room	Acct #			Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a		Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a
Comments:																							
Room	Acct #			Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a		Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a
Comments:																							
Room	Acct #			Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a		Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a
Comments:																							
Room	Acct #			Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a		Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a
Comments:																							
Room	Acct #			Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a		Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a
Comments:																							
Room	Acct #			Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a		Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a	Yes No n/a
Comments:																							

Appendix H

Software Citations

Package Name	Citation
R	R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.
tidyverse	Wickham et al., (2019). Welcome to the tidyverse. Journal of Open Source Software, 4(43), 1686, https://doi.org/10.21105/joss.01686
MKinfer	Matthias Kohl (2020). MKinfer: Inferential Statistics. R package version 0.6. http://www.stamats.de