9-15-2020

Most Effective Nursing Interventions to Prevent Central Line-Associated Bloodstream Infections: A Critical Review of the Literature

Jacqueline M. Flint

Most Effective Nursing Interventions to Prevent Central Line-Associated Bloodstream Infections: A Critical Review of the Literature

A Senior Honors Thesis

Submitted in Partial Fulfillment of the Requirements
for Graduation in the Honors College

By
Jacqueline M. Flint
Nursing Major
Biology Minor

The College at Brockport
May 6, 2020

Thesis Director: Dr Susan Lowey, PhD, RN, CHPN, CNE, FPCN, Associate Professor

Table of Contents

Introduction

Nosocomial infections, otherwise referred to as hospital-acquired infections (HAIs), are defined by the Centers for Disease Control and Prevention (CDC) as infections that occur in association with devices used in medical procedures, such as catheters or ventilators (Centers for Disease Control and Prevention, 2014). HAIs monitored by the CDC include central line-associated bloodstream infections (CLABSIs), catheter-associated urinary tract infections (CAUTIs), ventilator associated pneumonia (VAP), surgical site infections (SSIs), and other infections caused by the bacterium *Clostridium difficile*. HAIs are among the leading causes of preventable morbidity and mortality in the United States. Though recent efforts to prevent the occurrence of HAIs have been effective in reducing their incidence, HAIs remain a significant issue in the United States. It is estimated that each year, approximately 1 in 25 hospital patients in the United States are diagnosed with at least one infection related to hospital care (CDC, 2017) and additionally 1 in 35 hospital patients are estimated to have at least one healthcare-associated infection on any given day (CDC, 2018a). Furthermore, medical costs of HAIs are significant and pose an economic burden in the U.S. Estimated annual direct medical costs of HAIs to United States hospitals ranges from $28.4 to $45 billion (Scott, 2009).

Catheter-Associated Urinary Tract Infection (CAUTI)

A urinary tract infection (UTI) is defined by the Centers for Disease Control and Prevention (CDC) as “an infection involving any part of the urinary system, including urethra, bladder, ureters, and kidney” (CDC, 2015a). UTIs are one of the most common types of healthcare-associated infections, accounting for more than 30% of infections as reported by acute care hospitals (CDC, 2015b). Among UTIs acquired in hospitals, approximately 75% are associated with the placement of a urinary catheter (CDC, 2015a). Catheter-associated urinary

tract infections (CAUTIs) occur when an infectious pathogen enters the urinary tract via migration along the outside of a catheter, or movement along the internal lumen of the catheter from a contaminated catheter drainage system (CDC, 2015b). There has been significant progress in the prevention and development of CAUTIs in acute care facilities across the United States in recent years. Overall, there has been about an 8% decrease in CAUTI incidence within the United States between 2017 and 2018 (CDC, 2019b). Though there has been advances in prevention of this infection, CAUTI continues to remain a significant issue in United States hospitals.

Ventilator Associated Pneumonia (VAP)

Ventilator associated pneumonia (VAP) is a serious and potentially fatal lung condition that develops in a patient who is on respiratory support via a ventilator. Ventilators are commonly used in patients who cannot adequately oxygenate themselves due to insufficient breathing patterns and improper lung expansion. These machines are essential to the care of seriously ill patients, however are susceptible to becoming invaded by infectious disease. A ventilator is placed in a patient's mouth, nose, or through a hole in the front of the neck. An infection may occur if pathogens enter through the tube and into the patient's lungs. VAP is defined as pneumonia that occurs "48-72 hours or thereafter following endotracheal intubation, characterized by the presence of a new or progressive infiltrate, signs of systemic infection (fever, altered white blood cell count), changes in sputum characteristics, and detection of a causative agent" (Kalanuria, Zai, Mirski, 2014). VAP accounts for nearly half of all cases of hospital-acquired pneumonia, and is estimated to occur in 9-27% of all mechanically ventilated patients (Kalanuria et al., 2014). According to the 2018 National and State HAI Progress Report, there was no significant change in ventilator associated events between 2017 and 2018 (CDC,

2019b). In fact, according to this report, fifteen states in the U.S. were preforming worse in VAP prevention than the 2015 national baseline (CDC, 2019b). There is significant need for improvement in patient care practices in United States healthcare facilities to prevent instances and development of VAP.

Surgical Site Infection (SSI)

Each year millions of surgical procedures are performed in the United Sates. Surgical interventions are necessary to treat acute and chronic diseases. In 2014 alone, a total of 14.2 million operative procedures were performed in the inpatient setting in United States hospitals (CDC, 2020b). Though surgical procedures are essential to providing care, they do carry the risk of infection development. Surgical site infections are defined as "an infection that occurs after surgery in the part of the body where the surgery took place" (CDC, 2019a). The CDC healthcare-associated infection prevalence survey found that there were an estimated 110,800 surgical site infections (SSIs) associated with inpatient surgeries in 2015 (CDC, 2020b). Though advances have been made in infection control practices, SSIs remain a substantial cause of morbidity, mortality, and prolonged hospitalization for patients.

Clostridium Difficile (C.diff)

Clostridium Difficile (C.diff) has become one of the most common health care-associated infections in United States hospitals. C.diff is a bacterium that invades the gastrointestinal system, causing diarrhea and colitis (CDC, 2018b). Risk factors for developing C.diff include: being 65 years or older, recent hospitalizations, a weakened immune system, and previous infection with C.diff or known exposure to the bacterium (CDC, 2018b). C. diff is spread via contact with those who have the infection. Recommendations from the CDC to prevent the

spread of C.diff include: washing hands with soap and water, using a separate bathroom if you have diarrhea, and taking showers with soap (CDC, 2018b). A study funded by the CDC in 2015 preformed an active population and laboratory based surveillance across ten geographic areas in the United States to identify cases of C.diff and their causes. A total of 15,461 cases of C.diff were identified in this study, 65% of which were health care-associated (Lessa et al., 2015). Of those 65% C.diff infections identified to be health care-associated, 24.2% had onset during hospitalization (Lessa et al., 2015). Conclusions of this study revealed that C.diff was responsible for nearly half a million infections and was associated with approximately 29,000 deaths in 2011 (Lessa et al., 2015). C.diff remains a significant issue and continues to be one of the most commonly developed hospital acquired infections in the United States.

Central Line-Associated Bloodstream Infection (CLABSI)

CLABSI is a significant risk factor for increased morbidity, mortality, cost of care, and length of stay for hospitalized patients. Of the various kinds of hospital acquired infections, CLABSIs are one of the most deadly with an estimated mortality rate of 12-25% for each infection (CDC, 2002). CLABSIs are defined by The Joint Commission as:

> A primary bloodstream infection (that is, there is no apparent infection at another site) that develops in a patient with a central line in place within the 48-hour period before onset of the bloodstream infection that is not related to infection at another site (The Joint Commission, 2012).

The utilization of central venous catheters is an essential component of modern health care throughout the world. Central line placement allows for the administration of medications, fluids, blood products, and parenteral nutrition as well as providing hemodialysis access and

hemodynamic monitoring (TJC, 2012). Though the use of central lines crucial to providing patient care, their use is associated with an increased risk of infection. CLABSIs result from the colonization of microorganisms on the catheter's external surface or the fluid pathway when the device is inserted or in the course of its use (TJC, 2012). There are several organisms that contribute to the development of HAIs and CLABSIs. A report conducted by Weiner-Lastinger et al. from the Division of Healthcare Quality Promotion, National Center for Emerging and Zoonotic Infectious Diseases, and Centers for Disease Control and Prevention, evaluated common pathogens and antimicrobial resistant patterns for HAIs that occurred during 2015-2017. Upon analyzing data reported to the CDC and National Healthcare Safety Network (NHSN) from 5,626 facilities among patients greater than or equal to eighteen years old, common pathogens and their prevalence across facilities were evaluated. According to this article, the fifteen most frequently reported organisms that lead to the development of HAIs include Escherichia coli, Staphylococcus aureus, selected Klebsiella spp, Pseudomonas aeruginosa, Enterococcus faecalis, Coagulase-negative staphylococci, Enterobacter spp, Enterococcus faecium, Proteus spp, Candida albicans, other Enterococcus spp, Bacteroides spp, Viridans group streptococci, other Candida spp, and Candida glabrata (Weiner-Lastinger et al., 2019).

Though there has been a 46% decrease in CLABSI occurrence in hospitals across the United States from 2008-2013, it is estimated that 30,100 CLABSIs still occur in intensive care units and acute care facilities each year (CDC, 2020a). Use of central lines is common in both intensive, and non-intensive care units. In the United States it is estimated that nearly three hundred million catheters are used annually; with approximately three million of those being central lines (TJC, 2012). The financial burden of a CLABSI is considerable as well. The

attributable cost per infection is estimated to be $34,508-$56,000, and the annual cost of caring for patients with central line-associated bloodstream infections ranges from $296 million to $2.3 billion (CDC, 2002). The cost of CLABSI is substantial, both in terms of morbidity and financial resources expended annually.

There has been a national push to standardize procedures to prevent CLABSI occurrence. According to the CDC's checklist for the prevention of central line-associated bloodstream infections, there are three main components to preventing CLABSIs: insertion, maintenance, and removal of central lines. Firstly, insertion practices must be followed properly. This includes preforming hand hygiene before insertion, adhering to aseptic technique, utilizing maximal sterile barrier precautions, choosing the best insertion site to minimize infections based on patient characteristics, preparing the insertion site with >0.5% chlorhexidine with alcohol, placing a sterile gauze or dressing over the insertion site, and utilizing a chlorhexidine impregnated dressing for patients eighteen years or older (CDC, 2011). Secondly, central line maintenance needs to be handled appropriately by complying with hand hygiene requirements, bathing intensive care unit (ICU) patients with a chlorhexidine preparation daily, scrubbing the access port thoroughly, using sterile devices to access catheters, immediately replacing soiled dressings, preforming routine dressing changes using aseptic technique, and changing administration sets for continuous infusions appropriately (CDC, 2011). Lastly, it is necessary to continuously evaluate the extended need for central lines. Daily audits to assess weather each central line is still needed is recommended, and unnecessary central lines should be promptly removed (CDC, 2011).

CLABSIs are serious yet often preventable infections when evidence-based guidelines are followed for the insertion and maintenance of central lines. The purpose of this literature

review is to focus on the maintenance aspect of CLABSI prevention, and evaluate the role of the nurse in implementing effective, evidence-based interventions to promote optimal care of central lines and prevention of CLABSIs. Interventions analyzed in this project will include: the use of CLABSI prevention bundles, educational strategies and training for healthcare personnel, daily chlorhexidine bathing, central line dressing changes, and disinfection of the catheter hub.

Significance in Nursing

Nurses serve an essential role in the proper maintenance of central lines and thusly the prevention, or development, of CLABSIs. Nursing personnel access central lines on a daily basis for several reasons such as medication administration, blood draws, and delivery of parenteral nutrition. It is crucial for nurses to be aware of current, effective, evidence-based interventions to optimize central line maintenance and prevent the instances of CLABSIs. By implementing effective evidence-based interventions into nursing care CLABSI occurrence will reduce, thusly decreasing cost of care and length of stay for hospitalized patients in addition to enhancing patient outcomes.

Research questions that were addressed in this review included the following: What are the most effective interventions that nursing staff can implement into routine care that reduces instances of CLABSIs? What makes an intervention effective? How easily can these interventions be implemented into practice? And, what should future maintenance protocols look like for CLABSI prevention?

The purpose of this review is to summarize current nursing approaches to preventing CLABSIs in hospital-based settings. This review will attempt to define what an ideal approach to

central line maintenance by nursing staff should look like in the future, based on the most current evidence.

Background

Central line-associated bloodstream infections are defined by the CDC as "a laboratory confirmed bloodstream infection where an eligible primary bloodstream infection (BSI) organism is identified and an eligible central line is present on the laboratory confirmed bloodstream infection (LCBI) date of event (DOE) or the day before" (CDC, 2020a). Central lines are defined as an "intravascular catheter at or close to the heart, or in one of the great vessels that is used for infusion, withdrawal of blood, or hemodynamic monitoring" (CDC, 2020a). Common vessels utilized for central line placement include: Aorta, Pulmonary artery, Superior vena cava, Inferior vena cava, Brachiocephalic veins, Internal jugular veins, subclavian veins, external iliac veins, common iliac veins, and femoral veins (CDC 2020a).

Several types of central lines are available and they come in various sizes, shapes, and materials. The type of catheter chosen is often dependent upon on the specific needs and preferences of the patient and health care provider, including the amount of time required for central line use (TJC, 2012). Based on their design, central lines can be divided into four major types: Nontunneled catheters, Tunneled catheters, Implantable ports, and Peripherally inserted central catheters (PICCs) (TJC, 2012). When compared to a typical intravenous line, a central line is larger, can stay in place for a longer amount of time, can deliver a large volume of liquids rapidly, and allows blood to be drawn easily. Central lines are essential for patients who require: intravenous medications to be administered over a prolonged period of time, such as antibiotics and chemotherapy, rapid delivery of large amounts of fluid or blood, direct blood pressure measurements in a large or central vein, frequent blood sampling, intravenous nutrition, or

hemodialysis treatments (American Thoracic Society, 2007). Though central lines come in varying shapes, sizes, and serve different functions, they are all susceptible to becoming infected and resulting in a CLABSI. Eligible central lines for CLABSI events are those that have been "in place for more than two consecutive calendar days (on or after central line day 3), following the first access of the central line, in an inpatient location, during the current admission" (CDC, 2020a).

The Joint Commission estimates that there are nearly 250,000 cases of CLABSI in the United States annually (TJC, 2012). As with other HAIs, CLABSI increases the cost of health care and prolongs length of stay for hospitalized patients by up to three weeks (TJC, 2012). The CDC suggests that cost per CLABSI is roughly $16,550, however costs associated with CLABSI have varied from $3,700 to $56,000 per infection (CDC, 2002), (TJC, 2012). Additionally, The Joint Commission estimates that the annual number of deaths associated with HAIs in the United States is estimated to be nearly 98,987, with CLABSI being the precipitating event of one third of these HAIs (TJC, 2012). Not only is CLABSI costly in terms of resources expended, but also in regards to morbidity and mortality. CLABSIs are serious yet often preventable infections when evidence-based guidelines are followed. By implementing effective CLABSI prevention measures into nursing practice, cost of CLABSI will significantly decrease in the United States.

Risk Factors for CLABSI

CLABSIs can develop for a variety of reasons, however, the characteristics of the central line, its insertion, and its post insertion maintenance have a significant impact on the overall risk of infection development (TJC, 2012). Risk factors for CLABSI can be broken down into two varieties: *intrinsic* and *extrinsic* factors. Intrinsic risk factors are those that are nonmodifiable characteristics of the patient, including: patient age, underlying diseases or conditions, and

patient gender (TJC, 2013a). Extrinsic risk factors are potentially modifiable factors associated with central line insertion or maintenance. These include: prolonged hospitalization before central line insertion, parenteral nutrition, millilumen central lines, lack of maximal barriers for central line insertion, femoral or internal jugular access site, multiple central lines, heavy microbial colonization at the insertion site, and central line insertion in an intensive care unit or emergency department (TJC, 2013a). Additionally, the material of the central lines themselves can influence the development of bloodstream infections. Some materials can enhance the adherence of certain microorganisms the catheter's surface while others can contribute to the development of fibrous sheath, biofilm, and clot formation (TJC, 2012). These are a few examples of catheter characteristics that can predispose patients to colonization of organisms and bloodstream infection.

Pathogenesis of CLABSI

Once a central line is placed, it can become infected by an organism either *extraluminally* or *intraluminally*. All catheters have a *lumen*, which is the inner space of the tube that transports liquids. Extraluminal contamination occurs when a patient's own skin organisms are present at the site of catheter insertion. These organisms are then able to migrate along the catheter's surface, into the subcutaneous tract surrounding the catheter, and result in infection (TJC, 2012). Extraluminal infection commonly occurs as a result of inadequate preprocedural skin preparation and is the most common source of infection for short-term catheters (CLs in place for less than ten days) (TJC, 2020). Intraluminal infection occurs when there is direct contamination introduced to the fluid pathway when the intravenous (IV) system is manipulated (TJC, 2012). For example, direct contamination of fluids may occur when health care personnel have had contact with "IV solution connection sites, access hubs, needleless connectors, tubing junctions,

or contamination with the patient's own body fluids or skin" (TJC, 2012). Once contamination occurs in this way, the causative organism is introduced directly to the patient's bloodstream via traveling inside of the lumen of the catheter. Intraluminal contamination has been associated with prolonged central line dwell time, usually ten or more days (TJC, 2012).

CLABSI Pathogens

Though there are a variety of pathogens that can result in a CLABSI, the most commonly reported causative agents of bloodstream infections are gram-positive skin organisms (TJC, 2012). These organisms include, but are not limited to, Staphylococcus aureus, Enterococcus, and Candida species (TJC, 2012). Additionally, it is important to consider the management of multidrug-resistant organisms (MDROs) that cause CLABSIs. According to the CDC, MDROs are defined as "microorganisms, predominately bacteria, that are resistant to one or more classes of antimicrobial agents" (CDC, 2015c). MDROs are responsible for nearly 20% to 67% of all CLABSIs, making it critical to understand the management strategy for these patients as well (Burnham, Rojek, Kollef, 2019). Of the various MDRO pathogens, many listed by the CDC's 2019 Antibiotic Resistance Threats Report are significant contributors to CLABSI development. These include: Staphylococcus aureus, Enterococcus, Enterobacteriaceae, Pseudomonas aeruginosa, and Acinetobacter (CDC, 2019c).

Interventions to Prevent CLABSI

Preventing the introduction of microorganisms to central lines is critical to the elimination of CLABSIs. In the past twenty years there has been significant efforts worldwide to develop effective evidence-based interventions to reduce the development of CLABSIs. Implementation of CLABSI prevention guidelines contributes to a significant reduction in the

rate of infection. Nurses are an essential component of modern health care and play a pivotal role in preventing CLABSI, because nurses are generally responsible for the routine care and maintenance of central lines. Nursing actions and compliance with best evidence-based practices have a direct impact on patient outcomes. Interventions preformed and adhered to by nursing staff are essential to preventing bloodstream infections.

Five nursing interventions that contribute to CLABSI prevention were identified and analyzed in this literature review. The interventions that will be discussed include: daily chlorhexidine bathing, central line dressing changes, disinfection of the catheter hub, educational strategies and training for healthcare personnel, and the use of CLABSI prevention bundles.

Chlorhexidine Bathing

Chlorhexidine gluconate (CHG) is an antiseptic solution that has broad spectrum activity against many organisms that cause CLABSI, including Staphylococcus aureus and Enterococcus spp. (Climo et al. 2013). The skin of patients is considered a major reservoir for pathogens associated with CLABSI. CHG decreases the presence of microbes on patients' skin, and prevents secondary environmental contamination of central lines (Climo et al. 2013). Additionally CHG solutions reside on the skin of a patient for a longer period of time than regular soap and other antiseptics, and therefore continues to protect patients after they are bathed (Reagan et al. 2019). Because CLABSIs can often result from the migration of organisms from the skin, along the catheter, and into the bloodstream, regular skin decontamination by CHG bathing could decrease CLABSI risk.

Standardized Dressing Maintenance

Once a central line is placed they are covered with a sterile dressing. Dressings are utilized to properly secure the central line, in order to prevent them from becoming dislodged, and to avoid infection. There are various kinds of dressings which can be used for the securement of central lines. Some of these products include: sterile gauze dressings, polyurethane dressings, chlorhexidine gluconate-impregnated dressings, and hydrocolloid dressings. Though there are several varieties of dressing products used in the maintenance of central lines, they all must be properly managed in order to prevent infection.

The CDC provides recommendations for the proper maintenance of central line dressings. According to their suggestions short term central line sites with gauze dressings should be changed every two days, short term central line sites with transparent dressings should be changed every seven days, and all dressings should be changed if it becomes damp, loosened, or visibly soiled (CDC, 2015d). Nursing staff are responsible for identifying soiled dressings, and replacing them as ordered. Accurate assessment of dressings and line insertion sites, prompt identification of soiled dressings, and proper aseptic replacement of dressings are essential nursing actions that contribute to CLABSI prevention. It is crucial for nurses to be knowledgeable about central line dressing care, and to be confident in dressing skills in order to prevent bloodstream infections.

Disinfection of Catheter Hubs

An important aspect of preventing intraluminal contamination of central lines is to ensure appropriate disinfection of the catheter hub prior to use. The hub of the catheter refers to the end of the central line that connects to other IV lines or a cap. If the hub of any venous access device is not properly sterilized prior to use, there is potential for introducing microorganisms to the lumen of the catheter. There are two commonly implemented interventions utilized to sterilize

catheter hubs. One intervention is scrubbing the catheter hub with an alcohol based solution prior to accessing it. Firstly hand hygiene should be performed, then clean or sterile gloves should be applied followed by using a scrubbing device with an alcohol product such as chlorhexidine with alcohol or 70% alcohol to rub the hub for ten to fifteen seconds (TJC, 2013c). Then, the hub should be allowed time to completely dry before being accessed (TJC, 2013c).

An alternative to scrubbing the catheter hub with an alcohol based solution for ten to fifteen seconds is the use of an antiseptic barrier cap, which sanitizes the catheter hub by continuous passive disinfection. These barrier caps are placed onto the catheter hub and bathes it's surface in 70% isopropyl alcohol (Voor in 't holt et al., 2017). Barrier caps are single-use and remain in place until the next catheter access. This design allows for continuous disinfection of the catheter hub, allows for safe access to the hub when the cap is removed, and reduces colonization of microorganisms on the hubs thereby lowering the risk of CLABSIs (Voor in 't holt et al., 2017). Both of these interventions, when implemented correctly, decreases risk of intraluminal contamination of the central line.

CLABSI Prevention Bundles

Care bundles are used widely across healthcare settings with a common aim of improving quality of patient care and preventing variation in delivery of care. Additionally, bundles assist in the prevention and management of various health conditions. Care bundles are a set of evidence-based practices preformed collectively to enhance patient outcomes. Care bundles are used within healthcare for various conditions such as prevention and management of CAUTI, VAP, and CLABSI.

Potential central line maintenance bundle components suggested by The Joint Commission include: daily review of line necessity with prompt removal of unnecessary central lines and documentation, details of removal documented in records, hand hygiene before manipulation of the IV system, considerations regarding catheter injection ports, proper procedures for catheter site dressing changes, considerations for catheter accesses and manipulation, guidelines for administration set replacement, infuscate preparation using aseptic technique, and healthcare personnel training (TJC, 3013d). The implementation of central line maintenance bundles have been validated in various clinical trials that have produced significant reductions in CLABSI. Standardized central line maintenance bundles, when properly adhered to, can considerably reduce CLABSI occurrence.

Education

A crucial aspect of CLABSI prevention is proper education and training of healthcare personnel. There is an emphasis on the importance of multidisciplinary care and awareness of updated CLABSI prevention guidelines through the education of health professionals. Though it is evident that effective educational strategies are essential to CLABSI prevention, studies have reported that nurses' current knowledge of these guidelines are poor (Aloush, 2018). Lack of sufficient knowledge may affect CLABSI prevention guideline compliance in the future, and increase prevalence of CLABSI. Though it is established that education is pivotal to the prevention of CLABSI, the best approach to nursing education for this issue is not clearly defined. A standardized approach to nursing education regarding central line maintenance will optimize patient care, and ultimately minimize CLABSI occurrence.

Final Thoughts

The CDC and The Joint Commission have created central line maintenance guidelines for the prevention of CLABSI. However, there is a lack of standardization and enforcement of guidelines across United States hospitals. Many healthcare facilities do have CLABSI prevention policies established, however procedures vary by institution. Additionally, routine assessment of nursing knowledge and competence in preforming central line care is not consistently evaluated. This literature review will examine current strategies for central line care, and will attempt to describe what an ideal nursing approach to central line maintenance should be to prevent CLABSIs.

Methods

A literature review was preformed to identify the most effective evidence-based nursing interventions to prevent the development of CLABSI, as well as evaluation of interventions. The discovery of research articles and other supporting literature was completed using electronic databases Medline, CINHAL, PubMed, and Cochrane. Additionally, studies were identified from the reference lists of relevant articles. Databases were searched for peer-reviewed articles published from the year 2000 to 2020. Keywords included *central line associated bloodstream infections, pathogens, CLABSI prevention, nursing interventions, central line maintenance, central line care, antiseptic capping, chlorhexidine bathing, routine dressing care, nursing education, scrub the hub, adults,* and *CLABSI bundles.*

The inclusion criteria for the articles that will be discussed in this literature review is as follows:

a. Articles must be peer-reviewed.
b. Articles must be either primary research studies or literature reviews.

c. Articles that are research studies must be approved by IRB or equivalent hospital administration.
d. Articles must be primarily focused on adult populations (18 years and older).
e. Articles are aimed at reducing CLABSI incidence during the maintenance portion of central line care.
f. Articles that describe interventions based in a hospital based environment.

Exclusion criteria are as follows:

a. Articles that primarily focus on CLABSI interventions for pediatric ages (0-17 years).
b. Articles primarily aimed at reducing CLABSI incidence during the insertion portion of central line care.
c. Articles with interventions based in an outpatient environment.
d. Articles published before the year 2000.
e. Articles primarily focused on the physician's role in the prevention of CLABSIs.

Articles retrieved from the databases were screened for applicability and the abstracts of those articles determined to be suitable were reviewed. Articles that met inclusion criteria and found to have utilized effective methodological standards were included in the sample for this literature review. The final search retrieval resulted in twenty-five articles to be reviewed. Publication dates of the twenty-five articles ranged from 2010-2020, and thirteen of the twenty-five were published within the past five years. It is important to note the inclusion criterion "articles must be *primarily* focused on adult populations (18 years and older)". This criterion was written as so because one research study included in this review was conducted at the Children's Hospital of Philadelphia (Scholtz, Monachino, Nishisaki, Nadkarni, Lengetti, 2013), and one literature review included data from adult ICUs, neonatal intensive care units (NICUs), and

pediatric intensive care units (PICUs) (Ista et al., 2016). Although the central focus of this literature review is CLABSI prevention in adult populations, these two articles were included in this review because the data was significant and can be readily applied to adult populations. It is also important to recognize the exclusion criterion "articles *primarily* focused on the physician's role in the prevention of CLABSIs". This criterion was written as such because some of the twenty-five articles included in this literature review evaluated the nurse's role in central line maintenance in addition to the physician's role in insertion of the central line. These articles were included in this review because pertinent data in regards to the maintenance portion of central line care was discovered. Additionally, it is valuable to note that there is no exclusion criterion listed for articles published outside of the United States. While some of the articles discussed CLABSI prevention methods in other countries, there is no plausible reason to exclude these studies. It is important to consider worldwide approaches to central line care in order to gather the most effective, current, and evidence-based strategies to prevent CLABSI.

Results

The search retrieval resulted in twenty-five articles, all of which had varying outcomes and central ideas in regards to CLABSI prevention. Of the twenty-five articles, three (12%) were literature reviews. Of these reviews, one discussed the effectiveness of chlorhexidine bathing among adult intensive care patients in reducing various infections in an intensive care unit (Frost et al., 2016), one assessed the effectiveness of the implementation of central-line bundles to prevent CLABSIs in adult, pediatric, and neonatal patients in intensive care units (Ista et al., 2016), and one analyzed the effect of antiseptic barrier caps compared to manual disinfection on the incidence of CLABSIs (Voor In 't Holt et al., 2017).

The remaining twenty-two articles (88%) were research studies. Of these studies, eighteen (82%) were conducted in the United States. The remaining studies were conducted in Saudi Arabia (1), Italy (1), Korea (1), and Switzerland (1), accounting for the remainder of 18%. Of the twenty two-research studies sample sizes varied from one hospital unit to a thirty-five hospital network. Within the sample of twenty two primary research articles, trials included: randomized control trials (2), pre-intervention post-intervention comparisons (7), pretest-posttest design (1), multicenter, cluster randomized, nonblinded crossover trial (1), observational cohort study using historical controls (1), cross-sectional design (1), retrospective pre- and post-intervention, quasi-experimental quality improvement study (1), multiphase prospective study (1), quasi-experimental design (3), prospective, 3-phase, multiple hospital study (1), nonrandomized prospective trial (1), discrete-time Markov Chain (1), and a prospective before and after timed series study (1).

Of these twenty two primary research studies four examined the effects of chlorhexidine bathing on CLABI prevention, four analyzed the effectiveness of educational interventions for hospital staff, one assessed nursing knowledge and behaviors regarding central line procedures, five examined the effect of catheter hub disinfection on reducing CLABSI incidence, two analyzed the effectiveness of standardized central line dressing changes, one assessed the impact of a central line insertion assessment score on CLABSI prevention, four examined the effects of a central line maintenance bundle on CLABSI incidence, and one investigated the effect of adopting a unit-based quality nurse dedicated to prevention of CLABSI.

The twenty five studies that are included in the final analysis are recent within the last ten years, with the majority being primary research studies. The variety of articles provides information regarding several nursing interventions which prevent CLABSI, and will help

conclusions and implications to be drawn for further research. Please refer to Table 1 for a summary of findings gathered from the articles included in this literature review.

Table 1. Literature Review Table

Article Name	**Year**	**Purpose**	**Type of study (review or research study) & sample size**	**Methods**	**Main Outcomes**
Aloush (2018) Lecture-based education versus simulation in educating student nurses about central line-associated bloodstream infection-prevention guidelines	2018	To evaluate student nurses' knowledge of CLABSI prevention guidelines and to compare the effectiveness of simulation and lecture-based education	Research Study 131 fourth-year nursing student participants divided into two groups	Randomized control trial	Student nurses' knowledge about CLABSI prevention guidelines was found to be poor. Both simulation and classroom lectures were effective in improving knowledge
Barsuk, Cohen, Mikolajczak, Seburn, Slade, Wayne (2015) Simulation-based mastery learning improves central line maintenance skills of ICU nurses	2015	To evaluate the impact of a simulation-based mastery learning curriculum on central line care and maintenance among ICU nurses	Research Study One CTICU, 49 nurse participants	Pretest-posttest design	ICU nurses in this study displayed large variability in their ability to perform central line maintenance tasks. The implementation of simulation learning resulted in significant improvement in each skill
Climo, Yokoe, Warren, Perl, Bolon, Herwaldt … Wong (2013) Effect of daily chlorhexidine bathing on hospital-acquired infection	2013	To evaluate the effectiveness of daily bathing with chlorhexidine-impregnated washcloths on the acquisition of MDROs and the incidence of hospital-acquired bloodstream infections	Research Study Nine intensive care and bone marrow transplantation units in six hospitals	A multicenter, cluster-randomized, nonblinded crossover trial	Daily bathing with chlorhexidine-impregnated washcloths significantly reduced the risks of acquisition of MDROs and development of hospital-acquired bloodstream infections

DeVries, Mancos, Valentine (2014) Reducing bloodstream infection risk in central and peripheral intravenous lines: initial data on passive intravenous connector disinfection	2014	To involve bedside nurses in identifying efforts to prevent bloodstream infections, and to evaluate the effectiveness of a disinfection cap at preventing bloodstream infections	Research Study Three intensive care units for three months, followed by hospital-wide implementation	Pre-intervention, Post-intervention comparison	Applying a disinfection cap to both peripheral IVs and central lines resulted in statistically significant bloodstream infection reductions
Dixon & Carver (2010) Daily chlorohexidine gluconate bathing with impregnated cloths results in statistically significant reduction in central line-associated bloodstream infections	2010	To assess the effectiveness of daily bathing with CHG-impregnated cloths to reduce the incidence of CLABSIs in the SICU	Research Study One nine-bed surgical intensive care unit in a Level I trauma center, 144 patients	An observational cohort study using historical controls	CLABSI incidence rates reduced when implementation of daily bathing with 2% chlorhexidine gluconate non-rinse cloths coupled with evidence-based prevention bundles were implemented
Dumyati, Concannon, Van Wijngaarden, Love, Graman … Shelly (2014) Sustained reduction of central line-associated bloodstream infections outside the intensive care unit with a multimodal intervention focusing on	2014	To evaluate the CLABSI burden in selected adult units outside the ICU and to prevent these infections through engagement, education of nursing staff, and standardization of best practices for CVC line care and maintenance	Research Study 37 Adult non-ICU wards at six hospitals	Prospective preintervention-postintervention design	Engagement and education of nursing staff on an evidence-based bundle for CVC insertion and maintenance resulted in a sustained reduction in CLABSI rates

central line maintenance					
Esposito, Guillari, Angelillo (2017) Knowledge, attitudes, and practice on the prevention of central line-associated bloodstream infections among nurses in oncological care: A cross-sectional study in an area of southern Italy	2017	To describe the level of knowledge, attitudes, and behavior regarding central line procedures among nurses working in cancer settings in Italian hospitals	Research Study Sixteen hospitals, 355 questionnaires	Cross-sectional design	Educational interventions are extremely important and should be implemented to address gaps in knowledge and practice
Frost, Alogso, Metcalfe, Lynch, Hunt, Sanghavi … Hillman (2016) Chlorhexidine bathing and health care-associated infections among adult intensive care patients: a systematic review and meta-analysis	2016	To identify trials assessing the effectiveness of CHG bathing to reduce risk of infection among adult intensive care patients	Systematic Review and Meta-analysis Seventeen trials	Online research retrieval	There is evidence for the benefit of daily bathing with CHG to reduce CLABSI and MRSA infections
Gohil, Yim, Quan, Espinoza, Thompson, Kong … Huang (2020) Impact of a central-line insertion site assessment (CLISA) score on localized insertion site infection to prevent central-	2020	To assess the impact of the central-line-insertion site assessment (CLISA) score on the incidence of local inflammation or infection or CLABSI prevention	Research Study One intensive care unit, one oncology ward	Retrospective pre- and post-intervention, quasi-experimental quality improvement study	The CLISA program reduced the incidence of localized central line inflammation, ensured timely response to localized insertion-site infection, reduced central line dwell time, and elevated the importance of

line-associated bloodstream infection (CLABSI)					central line monitoring for nurses and physicians
Grigonis, Dawson, Burkett, Dylag, Sears, Helber, Snyder (2016) Use of a central catheter maintenance bundle in long-term acute care hospitals	2016	To determine whether implementation of a central catheter maintenance bundle, together with a central catheter team and a compliance checklist, reduces the rate of hospital-acquired CLABSIs	Research Study 30 long-term acute care hospitals	Pre-intervention Post-intervention comparison	Application of a central line maintenance bundle resulted in sustained reduction in CLABSI rates in long-term acute care facilities for fourteen months
Ista, Van Der Hoven, Kornelisse, Van Der Starre, Vos, Boersma, Helder (2016) Effectiveness of insertion and maintenance bundles to prevent central-line-associated bloodstream infections in critically ill patients of all ages: A systematic review and meta-analysis	2016	"To assess the effectiveness of the implementation of central-line bundles to prevent CLABSIs in adult, pediatric, and neonatal patients in ICUs"	Systematic Review and Meta-analysis 96 records used in systematic review, 79 records used in meta-analysis	Online research retrieval	There is a significant association between the implementation of central-line insertion and maintenance bundles and reduction of the incidence of CLABSIs in all ICU settings.
Kamboj, Blair, Bell, Son, Huang, Dowling … Sepkowitz (2015) Use of disinfection cap to reduce central-	2015	To examine the impact of routine use of a passive disinfection cap for catheter hub decontamination in hematology-oncology patients	Research Study Three high risk units, followed by hospital-wide implementation	Multiphase prospective study	The use of central venous catheter disinfection caps is a practical and low-cost intervention for catheter care. Caps reduce CLABSI rates among high-

line-associated bloodstream infection and blood culture contamination among hematology-oncology patients					risk cancer patients and promote a hospital-wide reduction in contamination among blood cultures
Marsteller, Sexton, Hsu, Hsiao, Holzmueller, Pronovost, Thompson (2012) A multicenter, phased, cluster-randomized controlled trial to reduce central line-associated bloodstream infections in intensive care units	2012	To determine the causal effects of the use of a Comprehensive Unit– based Safety Program and an evidence-based bloodstream infection bundle in reducing central line-associated bloodstream infections in intensive care units	Research Study 45 Intensive Care Units from 35 Hospitals	A multicenter, phased, cluster-randomized controlled trial	There is a causal relationship between the use of a Comprehensive Unit– based Safety Program and an evidence based infection prevention intervention and reduced CLABSIs in participating ICUs. The role of the nurse as a leader is key for the success of quality improvement interventions.
Merrill, Sumner, Linford, Taylor, Macintosh (2014) Impact of universal disinfectant cap implementation on central line-associated bloodstream infections	2014	To analyze the effect of universal IV needleless connector disinfectant cap implementation on the rate and type of CLABSI and estimated costs in a large tertiary care center using a standard central line bundle	Research Study 430 bed tertiary care trauma I center, thirteen inpatient units	Quasi-experimental design	There is a relationship between implementation of a disinfectant cap and reduced rates of CLABSI, cost, length of stay, and mortality
Montecalvo, McKenna, Yarrish, Mack,	2012	To determine the impact and sustainability of	Research Study One medical intensive care unit	A prospective, 3-phase,	Chlorhexidine bathing is associated with reductions in

Maguire, Haas … Wormser (2012) Chlorhexidine bathing to reduce central venous catheter-associated bloodstream infections: impact and sustainability		the effect of chlorhexidine bathing on central venous catheter-associated bloodstream infection	and one respiratory care unit of a tertiary care hospital, and four medical-surgical units of community hospitals	multiple hospital study	central venous catheter-associated bloodstream infection
Park, Ko, An, Bang, Chung (2017) Implementation of central line-associated bloodstream infection prevention bundles in a surgical intensive care unit using peer tutoring	2017	To evaluate the effectiveness of implementing CLABSI prevention bundles using peer tutoring	Research Study One SICU, fifteen bed unit	Pre-intervention Post-intervention comparison	Implementation of CLABSI prevention bundles using peer tutoring was effective in reducing CLABSIs
Ramirez, Lee, Welch (2012) Central venous catheter protective connector caps reduce intraluminal catheter-related infection	2012	To assess the effectiveness of the Curos Port Protector in reducing CLABSI incidence in comparison to scrubbing the catheter hub for fifteen seconds with an alcohol sponge	Research Study Two intensive care units in one hospital	Nonrandomized prospective trial	Consistent use of antiseptic caps in combination with utilization compliance does influence CLABSI rates
Reagan, Chan, Vanhoozer, Stevens, Doll, Godbout … Bearman (2019) You get back what you give:	2019	To assess the impact of CHG patient bathing on CLABSIs, CAUTIs, and hospital-onset C.diff infections	Research Study 850 simulated patients	Discrete-time Markov Chain	As CHG bathing compliance increases, yearly HAIs decrease, and the overall cost associated with HAIs also decreases

decreased hospital infections with improvement in CHG bathing, a mathematical modeling and cost analysis		and the associated costs			
Scholtz, Monachino, Nishisaki, Nadkarni, Lengetti (2013) Central venous catheter dress rehearsals	2013	To investigate if the implementation of a central venous catheter dress rehearsal program would improve nurses' knowledge, confidence, and psychomotor performance on mannequins in addition to real patients, and to assess if improvement in these areas would be temporally associated with hospital-wide decreases in CLABSI rates	Research study 430 bed tertiary care institution	Prospective before and after timed series study	A novel simulation-based mastery learning CVC dress rehearsal education program improved nurse's knowledge, self-confidence, and psychomotor skill performance on mannequins in addition to real patients, and were temporally associated with decreased hospital CLABSI rates
Thom, Li, Custer, Preas, Rew, Cafeo … Lissauer (2014) Successful implementation of a unit-based quality nurse to reduce central line-associated bloodstream infections	2014	To investigate the use of a single, unit-based nurse dedicated to CLABSI prevention	Research Study One SICU, nineteen bed unit	Quasi-experimental design	Presence of the unit-based quality nurse was highly correlated with CLABSI reduction

Voor In ‘t Holt, Helder, Vos, Schafthuizen, Sülz, Van Den Hoogen, Ista (2017) Antiseptic barrier cap effective in reducing central line-associated bloodstream infections: A systematic review and meta-analysis	2017	To compare the effectiveness of antiseptic barrier cap use and manual disinfection on the incidence of CLABSIs	Systematic review and Meta-analysis Nine articles	Online Research Retrieval	Use of the antiseptic barrier cap can lower the occurrence of CLABSIs and is cost saving
Williams (2015) Use of a policy-driven education program to reduce central line-associated bloodstream infection rates	2015	To evaluate the effectiveness of chlorhexidine site cleaning and staff education programs on infection-control practices to reduce CLABSI rates	Research Study A twenty five bed critical access hospital, 73 staff participants in education intervention	Pre-intervention Post-intervention comparison	Implementation of an educational program covering topics associated with CLABSI and CLABSI prevention resulted in a statistically significant increase in participant knowledge
Wright, Tropp, Schora, Dillon-Grant, Peterson, Boehm …Peterson (2013) Continuous passive disinfection of catheter hubs prevents contamination and bloodstream infection	2013	To evaluate the effectiveness of a disinfection cap with 70% alcohol in preventing contamination and infection in adult patients with central lines	Research Study 799 participants	A 3-pased, multifacility, quasi-experimental study	The implementation of alcohol impregnated caps resulted in less contamination and infection rates
Yaglowski (2020) All-Inclusive Central Line	2020	To assess the effectiveness of a CLABSI prevention Lean team, and	Research Study Seven-hospital network	Pre-intervention Post-intervention comparison	The implementation of all-inclusive central line dressing kits by the Lean team led to

Dressing Kits: A Lean Approach		development of all-inclusive dressing kits, and elimination of CLABSI			significant and sustained CLABSI rates
Zingg, Cartier, Inan, Touveneau, Theriault, Gayet-Ageron … Walder (2014) Hospital-wide multidisciplinary, multimodal intervention programme to reduce central venous catheter-associated bloodstream infection	2014	To test the effectiveness of a hospital-wide strategy on CLABSI reduction, including central line insertion training and a modular e-learning program for catheter care	Research Study One 1,908 bed primary and tertiary care center	Pre-intervention Post-intervention comparison	Reduction of hospital-wide CLABSI was reached with a comprehensive, multidisciplinary and multimodal quality improvement program which included aspects of behavioral change, and key principal of good implementation practice

Findings

Daily Chlorhexidine Bathing

Of the twenty-five articles analyzed in this literature review, five investigated the effect of daily chlorhexidine bathing on the instance of CLABSI aquisition. Four of these articles were primary studies and one was conducted as a systematic review and meta-analysis. Of the primary studies three assessed the daily use of 2% chlorhexidine impregnated washcloths on CLABSI incidence versus either traditional soap and water bathing or washing with a nonantimicrobial cloth, and one analyzed the impact of CHG patient bathing on various HAIs and the associated costs. Studies were conducted across ICUs, a respiratory care unit, and bone marrow transplant units. Results from these articles indicated that there was a sustained decrease in CLABSI incidence with the daily use of CHG bathing in comparison to the other two cleaning techniques. One of these studies also found that CHG bathing reduced transmission of resistant organisms, in addition to deceasing central-catheter fungal infections (Climo et al., 2013). The literature review included investigated the effect of CHG bathing in ICU settings. This review also found that, of seventeen articles evaluated, daily bathing with CHG bathing reduces incidence of CLABSI and MRSA infections in the ICU (Frost et al., 2016). However, this review emphasized that the effectiveness of CHG bathing was dependent on the underlying risks of these events in the given ICU (Frost et al., 2016).

Three of the four primary articles evaluated the cost-effectiveness of CHG bathing. One article studied the effect of CHG bathing on CLABSIs, CAUTIs, hospital-onset C.diff infections, and the associated costs (Reagan et al., 2019). In this study, a discrete-time Markov Chain was developed to model the movement of individuals between newly admitted patients who had not yet received a CHG bath in zero, one, or two days, patients whose most recent CHG bath was

zero, one, two, or three days ago, and patients who had an HAI (Reagan et al., 2019). CHG bathing compliance was varied, and HAI incidence and costs associated were analyzed. Results revealed that at a "32% reduction in HAI incidence, increasing CHG bathing compliance from 60% to 90% results in 20 averted infections and $815,301.75 in saved cost" (Reagan et al., 2019). A second article estimated that implementation of CHG impregnated washcloths resulted in cost savings during their intervention period of approximately $728,820 (Dixon & Carver, 2010). Lastly a third article estimated that, with investment in CHG washcloths, there would have been an increased expenditure ranging from $79,867 to $81,006 during their active intervention period (Montecalvo et al., 2012). However, there were twenty-one fewer central line associated bloodstream infections during this time (Montecalvo et al., 2012). Referring to an attributable cost estimate of $45,000 per CLABSI, an overall savings of approximately $945,000 would have been obtained during this intervention (Montecalvo et al., 2012).

Overall, findings from these five articles show evidence that daily CHG bathing reduces CLABSI in addition to incidence of other infections. Furthermore, with proper compliance by hospital staff, CHG bathing is substantially cost-effective. The cost of investing in daily CHG bathing is significantly less than the financial burden of a CLABSI case. Daily bathing with CHG washcloths is a straightforward, evidence-based intervention that can be implemented easily into routine nursing care and decrease CLABSI occurrence.

Central Line Dressing Maintenance

Common issues surrounding central line dressing maintenance include: lack of dressing kit standardization, inconsistencies in practice, lack of established methods to assess whether lines are at risk for CLABSI development, and substandard communication between

interprofessional teams. Three primary articles included in this review investigate these issues and propose effective, evidence-based methods to counter these problems.

Central line dressing kits are not universally standardized. In many cases, generic kits are used to preform central line dressing changes. However, issues with generic kits may include: items in kits not being specific to the dressing, items in kits being unused, extra items being needed for dressing changes, and supply issues existing (Yaglowski, 2020). In addition to these problems, nurses may be searching for additional supplies required to perform a proper dressing change from thirty seconds to upwards of twenty-five minutes when generic kits do not contain all of the items needed (Yaglowski, 2020). In order to combat these issues, one study created standardized dressing kits and evaluated their associated effects on dressing maintenance across a seven-hospital network (Yaglowski, 2020). Results from this study found that implementation of standardized central line dressing kits decreased time needed for nurses to gather supplies to less than one minute 100% of the time, resulted in a potential cost savings of $57, 600, decreased staff frustration in searching for supplies, created more time spent with the patient, and, most importantly, decreased CLABSI rates (Yaglowski, 2020).

Inconsistencies in practice and lack of adherence to the catheter maintenance and dressing change policy by nursing staff can contribute to CLABSI incidence. To address this safety issue, one study developed and implemented a central line dress rehearsal program. Central aims of this study were to assess whether this strategy would impact skill and knowledge acquisition, demonstration of clinical effectiveness, and association with improvement of patient or systemwide health outcomes (Scholtz, Monachino, Nishisaki, Nadkarni, Lengetti, 2013). This central line dress rehearsal program consisted of a pre-dress rehearsal questionnaire, a hands-on simulated dressing change preformed on a mannequin with direct observation from a clinical

educator, and a post-dress rehearsal questionnaire (Scholtz et al., 2013). Nurses attended these sessions two to four times a week and CLABSI rates were reviewed and compared before, during, and at twenty months after implementation of this program (Scholtz et al., 2013). Results from this study revealed that implementation of this strategy improved nurse's knowledge, self-confidence, and psychomotor skill performance on mannequins (Scholtz et al., 2013). Improvements were associated with enhanced competence on patients in the clinical practice, and hospital CLABSI rates temporarily decreased (Scholtz et al., 2013). These findings suggest that utilization of a central line dress rehearsal program improves nursing skills and prevents CLABSI incidence. Although this study was conducted in a pediatric setting, a central line dress rehearsal program could easily be applied to an adult population and has the potential to produce similar outcomes.

An important component of CLABSI prevention is prompt identification of central lines that may be at risk for infection development. Routine assessment of dressings and line insertion sites by nursing staff is essential to ensure early recognition of these signs and symptoms. A standardized assessment tool to evaluate central line insertion sites may promote attention to line-site care, and ultimately decrease development of CLABSIs. One study evaluated if the use of a standardized nurse-physician central line insertion assessment (CLISA) score would improve central line care, reduce local and systemic infection, and/or prompt proactive removal of symptomatic lines (Gohil et al., 2019). The CLISA score was used to assess erythema and drainage at line insertion sites, and quantified the degree of erythema from a scale of zero to three (Gohil et al., 2019). CLISA scores were documented in electronic medical records each shift, could instantly be seen by attending physicians, and provided an objective assessment method for both nurses and physicians. Results from this study determined that documenting a

CLISA score each shift enhanced interprofessional communication, resulted in rapid removal of lines with purulent insertion sites, improved attention to line site care, enchased discussions related to line removal, and decreased CLABSI occurrence by one-quarter in the year following application of this intervention (Gohil et al., 2019).

Overall, nursing knowledge, self-confidence, and accurate dressing skills are essential to CLABSI prevention. Central line dress rehearsal programs may contribute to enhancing nursing knowledge and hands on skills related to dressing maintenance. Additionally, standardized dressing kits can significantly reduce time needed to gather dressing supplies and be cost effective. Lastly, routine assessment of insertion sites and dressings can be documented via a CLISA score and promote prompt removal of lines at risk for CLABSI development. All three of these evidence-based nursing interventions enhance central line care, and can reduce CLABSI incidence.

Disinfection of Catheter Hubs

Six articles included in this review investigated the efficacy of antimicrobial impregnated caps on CLABSI prevention and their associated outcomes. Articles consisted of five primary research studies and one systematic review and meta-analysis. All articles investigating the effect of adding an antimicrobial cap into central line care found that consistent use of the antiseptic barrier cap, in addition to routine utilization compliance, can lower the occurrence of CLABSI.

Traditional methods of central line catheter decontamination included “scrub the hub” techniques, as previously discussed in this review. Three of the five primary articles assessed implementation of antimicrobial caps versus the traditional “scrub the hub” techniques. Though disinfection of hubs via manual alcohol swabbing has been utilized as a standard procedure, this

practice can be compromised due to technique variation and noncompliance (DeVries, Mancos, Valentine, 2014). Cap implementation was determined to eliminate variation in practice because they only twist onto the hub threads one way, and the bright orange color of the caps makes confirming compliance easy (Devries et al., 2014). Antimicrobial cap use was found to decrease variation in practice in addition to reducing CLABSI. One study assessed cap use in a pre-intervention post-intervention design. The pre-intervention period consisted of a baseline practice of scrubbing the hub, intervention period utilizing the antimicrobial caps, and post-intervention period returning to baseline practice (Wright et al., 2013). Results showed that 12.7% fewer patients had bacterial organisms recovered from their central lines during the intervention period (Wright et al., 2013). Once caps were removed and baseline practice was resumed during the post-intervention period, the percent of patients with intraluminal contamination increased to 12%. (Wright et al., 2013). Results from other articles support these findings as well. In other studies, central line bloodstream infection rates decreased 49.3% (Devries et al., 2014), 34% (Kamboj et al., 2015), and by 1.4 infections per 1,000 catheter days (Ramirez, Lee, Welch, 2012) after shifting from scrubbing methods to the disinfectant cap use. Use of passive disinfection caps were also found to decrease blood culture contamination by 51% in general oncology units and by 63% in high-risk units (Kamboj et al., 2015).

A notable finding consistently established across included studies was that compliance with cap use by staff is essential to reducing CLABSI. One study definitively found that as compliance with cap utilization increases, infection rates decrease. In this article, a 10% increase in compliance resulted in a 7% drop in infection (Merrill, Sumner, Linford, Taylor, Macintosh, 2014). Though it is established that strict adherence to these guidelines is necessary for infection prevention, compliance rates continued to vary during intervention periods. In another article,

compliance with cap use ranged from 25% to 100% during their intervention period (Ramirez et al., 2012). The cause of varying utilization compliance was found to be due to lack of cap availability at the bedside (Ramirez et al., 2012). In order to resolve this issue, a decision was made to add cap strips that could be hung on IV poles in patient rooms (Ramirez et al., 2012). After attaching the strips, average compliance increased from 63% to 80% (Ramirez et al., 2012).

In addition to reducing CLABSI occurrence and contamination of blood cultures, antimicrobial caps were found to be cost effective. All studies that discussed costs associated with cap use concluded that this intervention is cost saving. That is, the cost of implementing antimicrobial caps was significantly less than cost per CLABSI infection. Estimated net cost savings across the included articles ranged from $39,050 - $3,268,990 (Ramirez et al., 2012; Kamboj et al., 2015; Wright et al., 2013; Merrill et al., 2014).

Use of "scrub the hub" techniques remain controversial despite its recommendation by The Joint Commission for practice. Though this method can be effective when implemented correctly, differences in execution is prevalent. The addition of antimicrobial caps into central line care would eliminate this variation. However, in order to ensure appropriate compliance, caps should be readily available at the bedside. Overall, these findings show that use of a continuous passive disinfection cap can lower the occurrence of CLABSIs and is cost effective when compliance is adhered to.

CLABSI Prevention Bundles

Of the twenty-five articles included in this review, six discussed CLABSI prevention bundles. Five of these articles were primary studies, and one was a systematic review and meta-

analysis of ninety-six records. All studies assessing the effectiveness of CLABSI bundles found that there is a significant association between implementation of central line insertion and maintenance bundles and sustained reduction of CLABSIs.

Bundles discussed among these articles included components such as: dressing change checklists, educational sessions, hand hygiene, aseptic technique, regular assessment of central lines, and use of antiseptic caps (Marsteller et al., 2012; Dumyati et al, 2014; Grigonis et al., 2016). Use of CLABSI maintenance bundles was found to produce a significant reduction in CLABSI across all articles. Decrease in CLABSI rates ranged from 29% - 70% (Marsteller et al., 2012; Dumyati et al., 2014; Grigonis et al., 2016). Of these studies, one implemented a nurse-led program which included a central line insertion bundle for physicians in addition to a maintenance bundle for nurses. Nurses were identified as the drivers of this intervention on the interdisciplinary team, and were responsible for tasks such as: using a checklist to ensure clinicians were following evidence-based guidelines when inserting central lines and enforcing a central line maintenance bundle (Marsteller et al., 2012). Not only were CLABSI rates reduced during the intervention period, but this study showed that nurses can effectively drive an interdisciplinary safety program in their units (Marsteller et al., 2012). These finding show that nurses play a key role in the success of central line bundles. Additionally, this article emphasizes that interdisciplinary teamwork is essential to CLABSI prevention.

Though it is evident that maintenance bundles are successful at preventing CLABSI, appropriate compliance by healthcare staff to these guidelines is necessary in order for this intervention to be effective. Although objectives identified in bundles are evident and simple, the implementation of guidelines in the clinical practice requires several factors to be well-coordinated (Park, Ko, An, Bang, Chung, 2017). One study included in this review found that,

despite the use of a CLABSI prevention bundle adhering to best practices, lack of engagement was identified among nursing leadership, physicians, and frontline staff (Dumyati et al., 2014). Lack of engagement in bundles may result in decreased compliance, and ultimately the development of CLABSI. To combat this issue, a study conducted by Park et al. utilized a "learning by teaching" education method to enforce CLABSI prevention bundles (Park et al. 2017). Educational sessions for nurses held during this intervention period were taught by the nurses themselves (Park et al., 2017). This technique was designed so that all nurses served as a lecturer, and all nurses had the opportunity to actively study and discuss CLABSI-related issues (Park et al., 2017). Results from this article found that use of this teaching method reduced CLABSI rates, adherence to maintenance bundles achieved 100% by the second month of this intervention, resistance to a new job pattern by healthcare staff decreased, and awareness of core knowledge about CLABSI prevention practices increased (Park et al., 2017).

It is evident that CLABSI prevention bundles in addition to adequate compliance with these guidelines is effective at reducing CLABSI. However, one study found that despite implementing a best practice bundle in addition to unit champions and staff education, CLABSI rates at their institution remained above national benchmarks (Thom et al., 2014). In an attempt to resolve this issue, a unit-based quality nurse dedicated to CLABSI prevention was adopted on one unit at this institution (Thom et al., 2014). The central aim of this study was to assess whether the presence of a unit-based quality nurse would result in a decrease in CLABSI rates in one surgical intensive care unit (SICU) (Thom et al., 2014). Responsibilities of the nurse included: educating SICU staff regarding HAIs and prevention techniques, observing compliance with best practices (hand hygiene, completion of central line insertion checklists, and catheter maintenance), providing immediate and direct feedback to staff regarding best practices,

attending daily rounds, preforming daily assessments of central line necessity, observing central line insertions, and monitoring central line dressings (Thom et al., 2014). Results of this study found that there was a 70% reduction in CLABSI after the incorporation of a unit-based quality nurse (Thom et al., 2014). Additionally, implementation of this intervention has the potential to be cost effective. This study estimated that the presence of the unit-based quality nurse could save a one-year total of $205,200 (Thom et al., 2014).

Incorporation of CLABSI prevention bundles into patient care produces a significant and sustained reduction in CLABSI rates. Compliance with bundle guidelines is crucial to the success of this intervention, and may be enforced with a “learn by teaching” approach. Lastly, the presence of a unit-based quality nurse dedicated to CLABSI prevention also reduces incidence of infection. All three of these interventions related to central line bundles are effective and, when combined, have the potential to substantially prevent CLABSIs.

Educational Interventions

Five of the primary articles included in this review discussed educational interventions regarding CLABSI. Articles investigated strategies to enchase knowledge of CLABSI, CLABSI prevention guidelines, and investigated nursing knowledge regarding these topics.

Two of these articles assessed knowledge of central line maintenance and CLABSI prevention measures. One study aimed to assess the level of nursing knowledge, attitudes, and behaviors regarding central line procedures (Esposito, Guillari, Angelillo, 2017). This article found that nurses have an overall adequate understanding of evidence-based measures for preventing CLABSIs, however level of knowledge significantly varies (Esposito et al., 2017). Though knowledge concerning type of dressing and frequency of dressing changes was found to

be adequate, there were areas where comprehension was substantially lower such as in agents used for skin antisepsis (Esposito et al., 2017). These findings suggest that knowledge regarding central lines and CLABSI differs among nurses, and there is a need for an increased amount of education regarding central line maintenance and CLABSI prevention. The second study aimed to evaluate student nurses' knowledge of CLABSI prevention guidelines. In this article, student nurses were given a test before and after a simulation or lecture-based educational session (Aloush, 2018). Results from this study found that overall knowledge scores in the pretest were poor, however implementation of an educational session improved posttest scores (Aloush, 2018).

Of the articles discussing CLABSI educational interventions, simulation-based learning, lecture-based learning, and modular e-learning were evaluated. Simulation-based learning provided nurses and nursing students with a hands-on approach to central line care. In one study, prior to implementation of simulation-based learning, a majority of experienced ICU nurses were unable to completely or consistently preform central line maintenance tasks (Barsuk et al., 2015). This suggests that, at baseline, nurses display a wide variability in their ability to perform central line procedures (Barsuk et al., 2015). A second article found that before simulation-based learning was introduced, level of student nursing knowledge regarding central line procedures was poor (Aloush, 2018). However, after a simulation-based session was conducted, there was significant improvement in student knowledge of routine change of central venous catheters, frequency of change for IV fluid administration sets, and frequency of change for total parenteral nutrition and blood administration sets (Aloush, 2018). Execution of simulation-based learning in these studies significantly improved knowledge and confidence in preforming central line maintenance tasks.

Though simulation-based education is effective, the equipment needed for this intervention can be expensive. Alternatives to this method of education could be lecture-based learning and modular e-learning, both of which were also found to be successful in this review. Lecture-based learning was found to improve student knowledge in regards to total parenteral nutrition and blood administration set changes, and the use of systemic prophylactic antibiotics to prevent CLABSI (Aloush, 2018). Additionally, knowledge improvements in frequency of dressing changes, site cleaning solutions, CLABSI identification, terminal tip locations, and site inspection for CLABSI were found across multidisciplinary teams after attending power point lectures (Williams, 2015). In one study, modular e-learning was utilized to train nursing staff on central venous catheter care hospital-wide (Zingg et al., 2014).The e-learning modules were found to be pragmatic, considering the large amount of nurses to be trained, and favorable among hospital staff (Zingg et al., 2014). Additionally, when e-learning for nursing staff was combined with simulation and lecture-based learning for physicians inserting central lines, CLABSI rates significantly decreased (Zingg et al., 2014).

These articles indicate that there is a lack of knowledge concerning CLABSI prevention guidelines and central line maintenance among nurses and nursing students. Insufficient understanding of CLABSI prevention guidelines increases risk for infection development and ultimately results in substandard patient outcomes. Education concerning these topics should be integrated further into nursing school education to ensure that new graduate nurses are confident in CLABSI prevention. Additionally, standardized nursing education via simulation-based, lecture-based, or e-learning should be implemented into hospital staff education on a routine basis.

Discussion & Conclusion

Outcomes

The findings of this literature review imply that there are several nursing interventions that currently exist which aim at reducing CLABSI occurrence. Use of chlorhexidine bathing, standardized dressing maintenance, antimicrobial caps, educational training for staff, and CLABSI prevention bundles all resulted in a sustained decrease in CLABSI occurrence in hospitalized adult patients. Additionally, many of these interventions improved nursing knowledge, confidence, interprofessional communication among staff members, and were determined to be cost effective. However, a common theme discovered across all articles was that appropriate compliance to these guidelines is necessary in order for interventions to be effective.

CLABSI remains prevalent issue across the United States despite advancements in healthcare. Findings from this review suggest that a combined approach to CLABSI prevention including all of the discussed interventions may be the most beneficial nursing approach to reducing CLABSI incidence at the bedside.

Implications in Nursing Practice

This literature review provides current, effective, evidence-based nursing interventions that significantly reduce CLABSI occurrence. Nurses that work in hospital-based settings with primarily an adult patient population should adopt strategies from this literature review and apply it to their individual practice. Application of utilizing chlorhexidine impregnated washcloths when bathing patients and teaching co-workers accurate methods to prevent CLABSI via a "learn by teaching" approach could be easily incorporated into individual practice. Though use of the strategies presented in this review may be used on an individual basis, information should

be applied and standardized across entire hospital settings. Nurse managers and leaders could utilize this information to adjust current procedures on their units in order to enchase CLABSI prevention guidelines. Strategies presented in this review that could be incorporated into unit practice include: use of a unit-based quality nurse to enforce current CLABSI prevention practices, implementation of routine CLABSI educational sessions via simulated-based, lecture-based, or modular e-learning, elimination of "scrub the hub" techniques and replacement with antimicrobial caps, and standardization of central line dressing changes.

Overall, incorporation of these interventions into current practice would be relatively simple. Though a universal, standardized model of CLABSI prevention guidelines pertaining to the maintenance portion of central line care has not yet been developed, nurses would be able to make changes to their current policies and procedures with the information provided in this review. Changes could be implemented hospital-wide, providing an increasingly standardized approach to CLABSI prevention and central line care.

Implications in Policy Development

Though this review did not focus specifically on policy development regarding CLABSI prevention, findings from this analysis may be relevant to current policy development. As previously discussed, the CDC and The Joint Commission have published guidelines presenting the best methods to prevent CLABSI (CDC, 2015d), (TJC, 2012). However, these procedures are merely recommendations and are thusly not universally standardized across all hospital settings. Additionally, these guidelines incorporate suggestions for both the insertion and maintenance portions of central line care. There is an issue that no one standardized CLABSI prevention model exclusively regarding central line maintenance currently exists. Findings from this review provide evidence for best practices associated with CLABSI prevention by nursing staff during

the maintenance portion of central line care. Researchers can take the information from this literature review and suggestions, as outlined above, to attempt to develop a single model CLABSI maintenance prevention technique. Although policy development may take a considerable amount of time, nurse managers and leaders could use the information from this analysis to enact change in CLABSI policies and procedures immediately at their own respective institutions.

Limitations

This literature review focused on determining the most effective, evidence-based nursing interventions to prevent CLABSI in adult hospitalized patients. However, there are a few limitations to this analysis. Firstly, a majority of the articles included in this review analyzed CLABSI prevention interventions in an ICU or acute care setting. These included fourteen of the twenty-two primary articles (64%) and two of the three literature reviews (67%). Though this does not nullify the proven effectiveness of the interventions presented in those studies, it does not certainly conclude that those interventions would be effective across all hospital settings. Additionally, some studies were single-centered and could not definitively be generalizable. Secondly, a few studies evaluated the effectiveness of both insertion and maintenance bundles on CLABSI incidence. Though maintenance bundles were deemed to be effective at reducing CLABSI, the combination of implementing both bundles at the same time could have inadvertently affected the final results. Reduction attributed to the maintenance bundles may in fact have been a result of the insertion bundles and vise vera. Thirdly, there are other nursing interventions aimed at reducing CLABSI which exist that were not specifically analyzed in this review. These interventions include: hand hygiene via hand washing with soap and water or alcohol-based solutions, and use of nursing checklists to ensure that appropriate procedures are

followed during insertion of a central line. Lastly, as with any literature review, there is potential weakness of missing unpublished trials. Also, articles included in this review were hand selected, therefore relevant articles pertaining to this topic may have been missed.

Future literature reviews should take these limitations into consideration and search for studies that implement interventions across a greater patient population in addition to articles that evaluate the effectiveness of a single intervention. Also, analysis software should be used to assure that all relevant articles are included in the review.

Future Model

The key research questions presented in the introduction of this literature review were, "What are the most effective interventions that nursing staff can implement into routine care that reduces instances of CLABSIs?", "What makes an intervention effective?", "How easily can these interventions be implemented into practice?", and "What should future maintenance protocols look like for CLABSI prevention?". After viewing the current research, all interventions analyzed were successful at reducing instances of CLABSI. Effectiveness was measured most commonly by infections per 1,000 catheter days during pre-intervention periods as compared to post-intervention periods. Interventions were relatively easy to be implemented into current practices, however compliance with guidelines varied. Though compliance was not adhered to 100% of the time across all articles, interventions created to increase compliance amongst the studies were effective. Future maintenance protocols for CLABSI prevention should include all elements discussed in this review. CLABSI prevention bundles are the best method for implementing many interventions at once in addition to standardizing practice.

Though standard prevention bundles in addition to routine CLABSI education for staff are the most effective methods for preventing infection, it is inevitable that compliance with bundles will vary across healthcare institutions. In order to combat this issue, incorporation of a unit-based quality nurse to enforce CLABSI prevention guidelines may increase compliance and reduce CLABSI rates, as proven in the literature. Additionally, a "learn by teaching" approach to CLABSI education provides staff with the opportunity to be increasingly hands-on in their education. This intervention may increase compliance as well as evidenced by the literature. Overall, the use of standardized CLABSI bundles which incorporate all of the evaluated interventions, when complied to properly, in addition to routine education for healthcare staff would be most effective in reducing CLABSIs.

Conclusion

This literature review attempted to summarize current evidence-based nursing interventions that are directed at CLABSI prevention, while answering various research questions aimed at seeking understanding of CLABSI prevention guidelines. After viewing the twenty-five articles it was determined that a prevention approach utilizing bundles in addition to routine staff education may be the most effective model presently. With appropriate compliance to these recommendations a beneficial, cost-effective, long-term outcome is likely to be seen.

Future studies should examine nursing interventions to prevent CLABSI across a wider adult patient population in hospital-based settings, and assess if the interventions found to be successful in this review can certainly be applied to other units. Interventions that failed to be included in this review should be studied in order to determine their effectiveness, and if inclusion of those interventions in a standardized maintenance bundle would further decrease

CLABSI incidence. Also, studies should attempt to evaluate single interventions exclusively in order to assure that their effectiveness is not attributed to another source.

To successfully enact change in the future, interdisciplinary teams must effectively work together. Nurses serve an essential role in the maintenance portion of central line care, and ultimately the prevention or development of CLABSI. Additionally, nurses may be one of the first staff members to recognize early indications of a bloodstream infection. Proper communication of these findings to the healthcare team is essential for the prevention and treatment of CLABSI. Ultimately, CLABSI is a multi-faceted issue and requires teamwork and collaboration amongst healthcare staff. However, a standardized approach to central line maintenance by nurses will decrease variation in individual practice, enchase knowledge and skills regarding infection prevention, and, most importantly, decrease CLABSI occurrence and improve patient outcomes.

References

Aloush, S.M. (2018). Lecture-based education versus simulation in educating nurses about central line-associated bloodstream infection-prevention guidelines. *Journal of Vascular Nursing, 37(2),* 125-131. DOI: 10.1016/j.jvn.2018.11.006

American Thoracic Society. (2007). Central Venous Catheter. Retrieved from: https://www.thoracic.org/patients/patient-resources/resources/central-venous-catheter.pdf

Barsuk, J.H., Cohen, E.R., Mikolajczak, A., Seburn, S., Slade, M., Wayne, D.B. (2015). Simulation-based mastery learning improves central line maintenance skills of ICU nurses. *The Journal of Nursing Administration, 45(10),* 511-517. DOI: 10.1097/NNA.0000000000000243

Burnham, J.P, Rojek, R.P., Kollef, M.H. (2019). Catheter removal and outcomes of multidrug-resistant central-line-associated bloodstream infection. *Medicine, 97(42),* 1-5. DOI: 10.1097/MD.0000000000012782

Centers for Disease Control and Prevention. (2020a). Bloodstream Infection Event (Central Line-Associated Bloodstream Infection and Non-central Line Associated Bloodstream Infection). Retrieved from: https://www.cdc.gov/nhsn/pdfs/pscmanual/4psc_clabscurrent.pdf

Centers for Disease Control and Prevention. (2020b). Surgical Site Infection (SSI) Event. Retreived from: https://www.cdc.gov/nhsn/pdfs/pscmanual/9pscssicurrent.pdf

Centers for Disease Control and Prevention. (2019a). Frequently Asked Questions About Surgical Site Infections. Retrieved from: https://www.cdc.gov/hai/ssi/faq_ssi.html

Centers for Disease Control and Prevention. (2019b). 2018 National and State Healthcare-Associated Infections Progress Report. Retrieved from: https://www.cdc.gov/hai/pdfs/progress-report/2018-Progress-Report-Executive-Summary-H.pdf

Centers for Disease Control and Prevention. (2019c). Antibiotic Resistance Threats in the United States, 2019. Retrieved from: https://www.cdc.gov/drugresistance/pdf/threats-report/2019-ar-threats-report-508.pdf

Centers for Disease Control and Prevention. (2018a). Healthcare-associated Infections: HAI Data. Retrieved from: https://www.cdc.gov/hai/data/index.html

Centers for Disease Control and Prevention. (2018b). Clostridioides difficile (C. diff). Retrieved from: https://www.cdc.gov/cdiff/index.html

Centers for Disease Control and Prevention. (2017). Healthcare-Associated Infections (HAIs). Retrieved from: https://www.cdc.gov/winnablebattles/report/HAIs.html

Centers for Disease Control and Prevention. (2015a). Catheter-associated Urinary Tract Infections (CAUTI). Retrieved from: https://www.cdc.gov/hai/ca_uti/uti.html

Centers for Disease Control and Prevention. (2015b). Guideline for Prevention of Catheter-Associated Urinary Tract Infections (2009). Retrieved from: https://www.cdc.gov/infectioncontrol/guidelines/cauti/background.html

Centers for Disease Control and Prevention. (2015c). Management of Multidrug-Resistant Organisms in Healthcare Settings (2006). Retrieved from: https://www.cdc.gov/infectioncontrol/guidelines/mdro/background.html

Centers for Disease Control and Prevention. (2015d). Summary of Recommendations: Guidelines for the Prevention of Intravascular Catheter-Related Infections (2011). Retrieved from: https://www.cdc.gov/infectioncontrol/guidelines/bsi/recommendations.html

Centers for Disease Control and Prevention. (2014). Types of Healthcare-associated Infections. Retrieved from: https://www.cdc.gov/hai/infectiontypes.html

Centers for Disease Control and Prevention. (2011). Checklist for Prevention of Central Line Associated Blood Stream Infections. Retrieved from: https://www.cdc.gov/hai/pdfs/bsi/checklist-for-CLABSI.pdf

Centers for Disease Control and Prevention. (2002). Guidelines for the Prevention of Intravascular Catheter-Related Infections. Retrieved from: https://www.cdc.gov/mmwr/preview/mmwrhtml/rr5110a1.htm?vm=r

Climo, M.W., Yokoe, D.S., Warren, D.K., Perl, T.M., Bolon, M.B., Herwaldt, L.A., … Wong, E.S. (2013). Daily chlorhexidine bathing-effect on healthcare-associated BSI and MDRO Acquisition. *The New England Journal of Medicine, 368(6),* 533-542. DOI: 10.1056/NEJMoa1113849

DeVries, M., Mancos, P.S., Valentine, M.J. (2014). Reducing bloodstream infection risk in central and peripheral intravenous lines: initial data on passive intravenous connector disinfection. *Journal of the Association for Vascular Access, 19(2),* 87-93. DOI: http://dx.doi.org/10.1016/j.java.2014.02.002

Dixon, J.M., Carver, R.L. (2010). Daily chlorohexidine gluconate bathing with impregnated cloths results in statistically significant reduction in central line-associated bloodstream

infections. *American Journal of Infection Control, 38(10),* 817-821. DOI: 10.1016/j.ajic.2010.06.005

Dumyati, G., Concannon, C., Van Wijngaarden, E., Love, T.M.T., Graman, P.G., … Shelly, M. (2014). Sustained reduction of central line-associated bloodstream infections outside the intensive care unit with a multimodal intervention focusing on central line maintenance. *American Journal of Infection Control, 42,* 723-730. DOI: http://dx.doi.org/10.1016/j.ajic.2014.03.353

Esposito, M.R., Guillari, A., Angelillo, I.F. (2017). Knowledge, attitudes, and practice on the prevention of central line-associated bloodstream infections among nurses in oncological care: A cross-sectional study in an area of southern Italy. *PLOS One, 2(16),* 1-11. DOI: 10.1371/journal.pone.0180473

Frost, S.A., Alogso, M., Metcalfe, L., Lynch, J.M., Hunt, L., Sanghavi, R., … Hillman, K.M. (2016). Chlorhexidine bathing and health care-associated infections among adult intensive care patients: a systematic review and meta-analysis. *Critical Care, 20(379),* 1-6. DOI: 10.1186/s13054-016-1553-5

Gohil, S.K., Yim, J., Quan, K., Espinoza, M., Thompson, D.J., Kong, A.P., … Huang, S.S. (2020). Impact of a central-line insertion site assessment (CLISA) score on localized insertion site infection to prevent central-line-associated bloodstream infection (CLABSI). *Journal of Infection Control and Hospital Epidemiology, 41,* 59-66. DOI: https://doi.org/10.1017/ice.2019.291

Grigonis, A.M., Dawson, A.M., Burkett, M., Dylag, A., Sears, M., Helber, B., Snyder, L.K. (2016). Use of a central catheter maintenance bundle in long-term acute care hospitals.

American Journal of Critical Care, 25(2), 165-172. DOI: http://dx.doi.org/10.4037/ajcc2016894

Ista, E., Van Der Hoven, B., Kornelisse, R., Van Der Starre, C., Vos, M.C., Boersma, E., Helder, O.K. (2016). Effectiveness of insertion and maintenance bundles to prevent central-line-associated bloodstream infections in critically ill patients of all ages: A systematic review and meta-analysis. *The Lancet, 16,* 724-734. DOI: https://doi.org/10.1016/S1473-3099(15)00409-0

Kalanuria, A.A., Zai, W., Mirski, M. (2014). Ventilator-associated pneumonia in the ICU. *Critical Care, 18(208),* 1-8. DOI: 10.1186/cc13775

Kamboj, M., Blair, R., Bell, N., Son, C., Huang, Y., Dowling, M., … Sepkowitz, K. (2015). Use of disinfection cap to reduce central-line-associated bloodstream infection and blood culture contamination among hematology-oncology patients. *The Journal of Infection Control and Hospital Epidemiology, 36(12),* 1401-1408. DOI: 10.1017/ice.2015.219

Lessa, F.C., Mu, Y., Bamberg, W.M., Beldavs, Z.G., Dumyati, G.K., Dunn, J.R., … McDonald, L.C. (2015). Burden of clostridium difficile infection in the united states. *The New England Journal of Medicine, 327(9),* 825-834. DOI: 10.1056/NEJMoa1408913

Marsteller, J.A., Sexton, B., Hsu, Y., Hsiao, C., Holzmueller, C.G., Pronovost, P.J., Thompson, D.A. (2012). A multicenter, phased, cluster-randomized controlled trial to reduce central line-associated bloodstream infections in intensive care units. *Critical Care Medicine, 44(11),* 2933-2939. DOI: 10.1097/CCM.0b013e31825fd4d8

Merrill, K.C., Sumner, S., Linford, L., Taylor, C., Macintosh, C. (2014). Impact of universal disinfectant cap implementation on central line-associated bloodstream infections.

American Journal of Infection Control, 42, 1274-1277. DOI: http://dx.doi.org/10.1016/j.ajic.2014.09.008

Montecalvo, M. A., McKenna, D., Yarrish, R., Mack, L., Maguire, G., Haas, J., … Wormser, G.P. (2012) Chlorhexidine bathing to reduce central venous catheter-associated bloodstream infections: impact and sustainability. *The American Journal of Medicine, 125(5),* 505-511. DOI: 0.1016/j.amjmed.2011.10.032

Park, S., Ko, S., An, H., Bang, J.H., Chung, W. (2017). Implementation of central line-associated bloodstream infection prevention bundles in a surgical intensive care unit using peer tutoring. *Antimicrobial Resistance and Infection Control, 6(103),* 1-7. DOI: 10.1186/s13756-017-0263-3

Ramirez, C., Lee, A.M., Welch, K. (2012). Central venous catheter protective connector caps reduce intraluminal catheter-related infection. *Journal of the Association for Vascular Access, 17(4),* 210-213. DOI: http://dx.doi.org/10.1016/j.java.2012.10.002

Reagan, K.A., Chan, D.M., Vanhoozer, G., Stevens, M.P., Doll, M., Godbout, E.J., … Bearman, G. (2019). You get back what you give: decreased hospital infections with improvement in CHG bathing, and mathematical modeling and cost analysis. *American Journal of Infection Control, 47,* 1471-1473. DOI: 10.1016/j.ajjc.2019.07.003

Scholtz, A.K., Monachino, A.M., Nishisaki, A., Nadkarni, V.M., Lengetti, E. (2013). Central venous catheter dress rehearsals. *Society for Simulation in Healthcare, 8(5),* 341-347. DOI:10.1097/SIH.0b013e3182974462

Scott, R.D. (2009). The Direct Costs of Healthcare-Associated Infections in U.S. Hospitals and

the Benefits of Prevention. Retrieved from: https://www.cdc.gov/hai/pdfs/hai/scott_costpaper.pdf

The Joint Commission. (2012). Preventing Central Line-Associated Bloodstream Infections: A Global Challenge, a Global Perspective. Retrieved from: file:///C:/Users/Owner/Downloads/CLABSI_Monographpdf%20(2).pdf

The Joint Commission. (2013a). Intrinsic and Extrinsic Risk Factors for CLABSI. Retrieved from: file:///C:/Users/Owner/Downloads/CLABSI_Toolkit_Tool_1-4_Intrinsic_and_Extrinsic_Risk_Factors_for_CLABSIpdf%20(2).pdf

The Joint Commission. (2013b). Intrinsic Risk Factors for CLABSI and Susceptible Populations. Retrieved from: file:///C:/Users/Owner/Downloads/CLABSI_Toolkit_Tool_1-5_Intrinsic_Risk_Factors_for_CLABSIs_and_Susceptible_Populationspdf.pdf

The Joint Commission. (2013c). Scrub the Hub!. Retrieved from: file:///C:/Users/Owner/Downloads/CLABSI_Toolkit_Tool_3-21_Scrub_the_Hubpdf.pdf

The Joint Commission. (2013d). CVC Maintenance Bundles. Retrieved from: file:///C:/Users/Owner/Downloads/CLABSI_Toolkit_Tool_3-22_CVC_Maintenance_Bundles%20(1).pdf

The Joint Commission. (2020). CLABSI Toolkit – Chapter 1: Types of Central Venous Catheters and Risk Factors for Pathogenesis of CLABSIs. Retrieved from: https://www.jointcommission.org/resources/patient-safety-topics/infection-prevention-and-control/central-line-associated-bloodstream-infections-toolkit-and-monograph/clabsi-toolkit---chapter-1/

Thom, K.A., Li, S., Custer, M., Preas, M.A., Rew, C.D., Cafeo, C., … Lissauer, M.E. (2014). Successful implementation of a unit-based quality nurse to reduce central line-associated bloodstream infections. *American Journal of Infection Control, 42,* 139-143. DOI: http://dx.doi.org/10.1016/j.ajic.2013.08.006

Voor in ‘t holt, A.F., Helder, O.K., Vos, M.C., Schafthuizen, L., Sülz, S., Van Den Hoogen, A., Ista, E. (2017). Antiseptic barrier cap effective in reducing central line-associated bloodstream infections: A systematic review and meta-analysis. *International Journal of Nursing Studies, 69,* 34-40. DOI: 10.1016/j.ijnurstu.2017.01.007

Weiner-Lastinger, L.M., Abner, S., Edwards, J.R., Kallen, A.J., Karlsson, M., Magill, S.S., … Dudeck, M.A. (2019). Antimicrobial-resistant pathogens associated with adult healthcare-associated infections: Summary of data reported to the National Healthcare Safety Network, 2015–2017. *Infection Control & Hospital Epidemiology, 41,* 1-18. DOI: 10.1017/ice.2019.296

Williams, D.W. (2015). Use of a policy-driven education program to reduce central line-associated bloodstream infection rates. *The Art and Science of Infusion Nursing, 38(1),* 63-68. DOI: 10.1097/NAN.0000000000000076

Wright, M., Tropp, J., Schora, D.M., Dillon-Grant, M., Peterson, K., Boehm, S., … Peterson, L.R. (2013). Continuous passive disinfection of catheter hubs prevents contamination and bloodstream infection. *American Journal of Infection Control, 41,* 33-38. DOI: http://dx.doi.org/10.1016/j.ajic.2012.05.030

Yaglowski, J. (2020). All-inclusive central line dressing kits: a lean approach. *Critical Care Nursing Quarterly, 43(1),* 99-106. DOI: 10.1097/CNQ.0000000000000296

Zingg, W., Cartier, V., Inan, C., Touveneau, S., Theriault, M., Gayet-Ageron, F., … Walder, B. (2014). Hospital-wide multidisciplinary, multimodal intervention programme to reduce central venous catheter-associated bloodstream infection. *PLOS One, 9(4),* 1-7. DOI: 10.1371/journal.pone.0093898