

Reducing Central Line-Associated Blood Stream Infections in the Neonatal Intensive Care Unit

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Scholarly Project

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Abstract

A central-line associated bloodstream infection (CLABSI) can be detrimental to any hospitalized patient, but neonates are especially fragile due to their immature immune system, repeated invasive procedures, and frequency of indwelling catheters. The high incidence of CLABSIs in the neonatal intensive care unit (NICU), coupled with the morbidity and mortality risks to this fragile population, placed this topic at the forefront of current research. Many prevention strategies have been identified in the research, but several gaps in the evidence remain. Continued research is critical to reducing CLABSI rates in the NICU population. Using Mefford's Theory of Health Promotion for Preterm Infants and based on Levine's Conservation Model of Nursing, this project examined several NICUs across the United States to determine their prevention strategies and CLABSI rates.

Key words: newborn infant, infection, incidence, nosocomial, premature infant, patient outcome assessment, epidemiology, length of stay, prevention and control

Reducing Central Line-Associated Blood Stream Infections in the Neonatal Intensive Care Unit

A central line associated-bloodstream infection (CLABSI) is an event that can be detrimental to a hospitalized patient at any age. When infants are born prematurely or ill, they require specialized care in a Neonatal Intensive Care Unit (NICU). These patients are especially vulnerable to the consequences of a CLABSI because of their compromised immune system and repeated invasive procedures (Anderson Berry, 2010). Many neonates in the NICU require central lines; either peripherally inserted central catheters (PICCs), umbilical lines, or Broviac lines for the purpose of long term intravenous (IV) nutrition, medication administration, or invasive monitoring. While the insertion of central lines is considered safe and effective, their use is not without risks. These risks include thrombosis, hemorrhage, arrhythmias, infections, effusions, catheter rupture, vessel perforation, obstruction, and extravasation. However, the greatest risk associated with central lines is the risk of hospital acquired blood stream infections (BSIs). These infections account for significant morbidity and mortality in the neonatal population, as well as numerous financial costs (Advani, Reich, Sengupta, Gosey, & Milstone, 2011).

Currently, more than five million central lines are inserted in the United States each year, and the Centers for Disease Control (CDC) estimates that 41,000 central line-associated bloodstream infections (CLABSIs) occur in U.S. hospitals each year (CDC , 2013). Helder, Brug, Looman, Van Goudoever, and Kornelisse (2010) reported that the incidence of nosocomial blood stream infections was between 11% and 53% in NICUs worldwide, and Suresh and Edwards (2012) estimated that over 33,000 infants a year contract hospital-acquired nosocomial

infections. These statistics demonstrate the significance of this problem in both the adult and neonatal population.

Neonates are especially vulnerable to CLABSIs due to contributing factors such as birth weight, gestational age, compromised immune system, and long hospitalizations (Borghesi & Stronati, 2008). Graham (2010) reported that an infant's birth weight was inversely proportional to the risk of a hospital-acquired infection (HAI). In recent decades, advancements in technology have allowed babies to be born at lower gestational ages and birth weights, increasing their vulnerability to HAIs, as well as their morbidity and mortality (Borghesi & Stronati, 2008). Studies have reported mortality rates from 11% to as high as 35.3% for infants with a CLABSI compared to a 9.1% mortality rate for those without a CLABSI (Powers & Wirschafter, 2010; Rosenthal et al., 2012).

Beyond mortality, the long-term effects of a CLABSI can be unfavorable. A recent Swiss study by Schlapbach et al. (2011) found an increase in neurodevelopmental impairment and cerebral palsy at two years corrected age in premature infants with proven sepsis, compared with those who did not have a sepsis event. Other adverse outcomes related to neonatal sepsis included an increased incidence of chronic lung disease, respiratory distress syndrome, intraventricular hemorrhage, and periventricular leukomalacia (Klinger et al., 2010; Lahra, Beeby, & Jeffery, 2009). The burden to society increases as adverse long-term effects increase, because these infants will become children who continue to require medical, behavioral, and developmental care.

Financial costs of treating patients with CLABSIs have also been shown to be a burden on families and the healthcare system. For a neonate, a single CLABSI can increase the length of stay (LOS) by four to seven days with a concurrent increase in hospital costs by \$5,875-

\$12,480 (Payne, Carpenter, Badger, Horbar, & Rogowski, 2004). Similar studies have estimated the cost of treating a nosocomial BSIs from \$6000 to \$39,000 per patient, and preventing these infections could save billions in healthcare dollars every year (Suresh & Edwards, 2012).

Neonates who experience a CLABSI do not do so in isolation. They are part of a larger community that includes their families, the government and insurance companies, and the health care professionals. All of these groups have a vested interest in the prevention of CLABSIs. As the wide-ranging repercussions of CLABSIs have been recognized, there has been a paradigm shift in the thinking regarding CLABSIs in the neonate. Once considered a treatment hazard, they are now considered medical errors due to their preventability (Suresh & Edwards, 2012).

Problem Statement

Hospitalized neonates, especially the very low birth weight (VLBW) infants, are more susceptible to CLABSIs because of their immature immune system and increased lengths of stay. In addition, the intensive care setting increases the frequency of contact with hospital staff along with the number of invasive procedures performed (Lee, 2011). Since CLABSIs are preventable, their avoidance should be at the forefront of patient safety priorities in all NICUs.

Purpose Statement

This project addressed current CLABSI rates of neonatal patients in six NICUs across the country from 2009 through 2013, along with the prevention strategies, practice changes, and infection control measures that were used. The main objective of this study was to add to the current knowledge base about the prevention strategies and best practice guidelines for CLABSI reduction in the neonatal population.

Theoretical Framework

Theories provide a framework or a way to examine a group of facts and the relationship of those facts to one another (O’Keefe, 2012). One theory that has been particularly useful in providing a way to see the interconnectedness of the concepts of neonatal CLABSIs is Mefford’s Theory of Health Promotion for Preterm Infants based on Levine’s Conservation Model of Nursing (Mefford, 2004). Using Levine’s Conservation Model as a foundation, Mefford explained her theory for the preterm infant this way: The goal of health for the preterm infant is a “conservation of wholeness” (Mefford, 2004, p. 261). She goes on to identify the four conditions that cause disturbances in this wholeness as physiologic immaturity, structural immaturity, neurologic immaturity, and disruption in family system (Mefford, 2004). Disruptions in each of these four areas are seen as “threats” (Mefford, 2004, p. 261), and the nursing role within this theory is to assist the neonate to adapt to these threats in order to maintain or return to a healthful state as evidenced by “physiologic stability and growth, minimal structural injury, neurodevelopmental competence, and a stable family system” (Mefford, 2004, p. 261). Each of the disruptions of Mefford’s theory, as well as nursing actions to return the infant to health, can be explored to describe how the elements of a neonatal CLABSI are interrelated and ultimately how important CLABSI prevention is to the neonate.

Physiologic Immaturity as a Threat to Physiologic Stability and Growth

The immaturity of the neonatal immune system and how it functions is particularly important in the context of CLABSIs. When neonates are exposed to pathogens, they do not have the appropriate immune response to fight the invading pathogen. Their limitations include decreased antibody levels, non-specific antibodies, and small numbers of neutrophils that do not function appropriately (Diehl-Jones & Askin, 2010). Therefore, instead of the neonates using

their energy for growth and development, the neonates use their energy to fight infection.

Nursing's role is to preserve energy for growth and development by preventing infection through such activities as hand hygiene and appropriate IV line care.

Structural Immaturity as a Threat to Minimal Structural Injury

The skin of a preterm infant is thinner and more permeable than an adult or even a full term infant, which makes the VLBW infant prone to the absorption of chemicals, transepidermal water loss, and injury from tape and other adhesives (Witt, 2010). This increases the risk for infection when a central or peripheral IV is inserted through skin that may have previous damage. Nursing's goal is to conserve the structural integrity of the skin by optimizing its barrier function through meticulous skin care. This includes gentle cleansing, aseptic technique with any invasive procedure, excellent hand hygiene, and minimizing the use of adhesives. These interventions are all techniques to prevent CLABSIs.

Neurologic Immaturity as a Threat to Neurodevelopmental Competence

Preterm neonates have an immature neurologic system with poor myelination and a decreased number of synapses and neurotransmitters (Goodwin, 2010). When a neonate experiences an infection, they suffer neurological consequences both in the short-term and the long-term (Stoll et al., 2004). Mefford (2004) states that Levine's Conservation Theory associates personal integrity to a person's "self-identity, self-worth, and self-esteem" (p. 263). While it's clear that personal integrity cannot be applied to a neonate in this exact way, it is also clear that infections, including CLABSIs, have long-term neurological ramifications that may interfere with the later development of a personal identity. Nursing's goal in this area should be to support appropriate neurodevelopmental outcomes and conserve neurodevelopmental competence. This can be accomplished by such interventions as minimizing stress by clustering

care and reading infant cues for overstimulation. The prevention of infection is also important to promote optimal neurologic growth and development.

Disruption in Family System as a Threat to a Stable Family System

The goal of nursing care in conserving a stable family system in the NICU is to facilitate the grieving process associated with loss of birth expectations and help parents adjust to their role as parents within the NICU environment. This is accomplished through education, involving parents in patient care, and allowing parent-infant bonding through holding and kangaroo care. If a neonate experiences a CLABSI it adds another stressor to a fragile family system and disrupts parent-infant attachment. For example, if a patient is too fragile from a medical standpoint as a result of a CLABSI, parents may not be able to participate intimately in their care or hold their infant. The prevention of CLABSIs is a vital part of preserving the neonate's family system, as it is in all the other areas of wholeness defined by Mefford.

Review of the Literature

To achieve a fuller understanding of CLABSIs, a literature review was conducted to explore and evaluate the current body of knowledge related to CLABSIs and their defining characteristics. The CDC collects infection data through a voluntary surveillance program at the National Healthcare Safety Network (NHSN) that is open to any unit or any type of healthcare organization in the U.S. Many research studies included in this review use CDC/NHSN criteria to identify CLABSIs (Rosenthal et al., 2011; Sengupta, Lehmann, Diener-West, Perl, & Milstone, 2010; Zingg, Posfay-Barbe, Pfister, Touveneau, & Pittet, 2011).

The CDC/NHSN definition had several criteria that needed to be met for a BSI to be classified as a CLABSI. First, a central line must be in place within 48 hours of the onset of infection. Second, a recognized pathogen must be cultured from one or more blood cultures and

not be related to an infection at another site. Third, the neonate must have demonstrated at least one sign or symptom from the following list: fever, hypothermia, apnea, or bradycardia. The final criteria stated that if a common skin contaminant, i.e. coagulase-negative *staphylococcus* (including *S. epidermidis*), was cultured it must be cultured and grown from two or more blood cultures from two separate sites (CDC, 2013). This portion of the definition can be applied to the neonate because the most common cause of CLABSI was coagulase-negative *staphylococcus* (CoNS) and because obtaining two cultures may have been more difficult in these small patients (Geffers et al., 2010; Hsu et al., 2010; Smith et al., 2008; Stoll et al., 2002). Several other definitions of CLABSI existed in the literature. For the purpose of this study the 2008 CDC definition for CLABSIs was used.

Incidence of Neonatal CLABSI

The reported incidence of CLABSIs in the literature was used in a number of ways. Incidence was used to establish baseline data, to benchmark a site or facility against other sites, facilities, or countries, and to evaluate the success or failure of an intervention (Balkhy et al., 2010; Fontela et al., 2012; Garland, Alex, Henrickson, McAuliffe, & Maki, 2005; Hill, Baldwin, Slaughter, Walsh, & Weitkamp, 2010; Navoa-Ng et al., 2011; & Rosenthal et al., 2008). Many of the articles cited in this review used the same formula for calculating incidence of CLABSIs:

$$\frac{\# \text{ of CLABSIs}}{\# \text{ of Catheter Days}} \times 1000.$$
 It is important to note that this measure is in wide use but it can be affected by alternate definitions of CLABSIs. In fact, in 2008, the CDC changed their defining characteristics for CLABSIs related to CoNS infections. This change in definition led to a natural decrease in the number of CLABSIs as fewer infections met the stricter criteria of two positive blood cultures (Stevens & Schulman, 2012).

Epidemiology of Neonatal CLABSI

According to Garland et al. (2008), a central line could become infected intraluminally, extraluminally, or by hematogenous seeding. Intraluminal infection occurs from an IV solution or a catheter hub that is contaminated. Extraluminal contamination occurs from organisms on the skin at the insertion site that migrate into the catheter track. Finally, hematogenous seeding occurs when bacteria is spread to the central line from another source of infection in the body. In a nested cohort study, Garland et al. (2008) concluded that most CLABSIs (67%) occurred as a result of intraluminal infections primarily from the catheter hub.

CoNS was the most common pathogen of neonatal CLABSI reported in the literature (Chien et al., 2002; Filipi, Pezzati, Di Amario, Poggi, & Pecile, 2007; Fontela et al., 2012; Garland et al., 2008; Perlman, Saiman, & Larson, 2007). This was expected for two reasons: first, CoNS species, such as *S. epidermidis*, are prevalent on the skin of both the infant and the healthcare provider; second, many types of CoNS produce a biofilm that helps the bacteria stick to medical devices such as central lines (Bartlett, 2011). Additional pathogens identified in the literature as causes of neonatal CLABSI included *Candida*, *Staphylococcus aureus*, *Streptococcus*, and *Enterococcus* (de Brito, de Brito, Abdallah, & Gontijo Filho, 2010; Garland et al., 2008). However, because CoNS was found to be the most common pathogen, the other pathogens received less attention in the literature.

Risk Factors for Neonatal CLABSI

Neonates are highly susceptible to a CLABSI and many variables have been studied to explain the reasons for this susceptibility. Some factors studied have a large body of evidence to support them and some do not. Identified risk factors are very important to the continued study

of CLABSIs because they will guide further research in prevention of CLABSIs by targeting the areas of greatest risk.

Prematurity. Prematurity as a risk factor for CLABSIs has been studied extensively in the literature and there was abundant evidence that the smaller the baby, either by gestation or birth weight, the higher the risk of CLABSIs (Anderson Berry, 2010; Borghesi & Stronati, 2008). The smaller or more premature the infant, the more immature the skin and immune systems are. Infants are also subjected to more invasive procedures (Lee, 2011). Geffers et al. (2010) and de Brito et al (2010) found that birth weight was a risk factor for the development of a CLABSI. Stoll et al. (2002) found both birth weight and gestational age to be risk factors for late onset sepsis that occurs after three days of life. This study examined a very large cohort of about 7000 infants. However, the limitation was that the authors did not specifically identify CLABSIs, only BSIs as a whole.

There were also a number of studies that did not find the same association between birth weight or gestational age and the risk of CLABSI. In a study by Hsu et al. (2010) the authors examined several risks factors for infection with the use of a PICC line in the VLBW infant and did not find either birth weight or gestational age to be a significant risk factor. Sengupta et al. (2010), in looking at dwell time as a risk factor for infection, also ascertained that there was no statistically significant risk between birth weight or gestational age and CLABSI. Likewise, Njere, Islam, Parish, Kuna, & Kestgar (2011) did not find that gestational age was a risk factor for CLABSI. This study had a small sample of only 218 infants; however, it included all gestational ages not just the VLBW infant which allowed for a broad comparison.

Type of central line. Several studies have examined whether the incidence of sepsis was greater from a peripheral line or a central line. Geffers et al. (2010) found that both central lines

and peripheral lines were risk factors for bloodstream infection and in almost equal measure. However, a limit of this study was that the authors looked only at VLBW infants (less than 1500 grams). This may predispose them to an infection from any type of invasive line, which could account for the almost equal BSI rate between central lines and peripheral lines. Chien et al. (2002) compared the incidence rate of CLABSI by line type and found that the use of a central catheter increased the risk of BSI. They also found that the risk from a PICC or Broviac was 70-80% higher than from an umbilical line. De Brito et al. (2010) identified PICC lines as having the highest risk of infection when compared to umbilical lines and other types of central catheters. Perlman et al. (2007) found that infants with a central line had a 9.3-fold increased risk of developing a BSI when compared with infants who did not have a central line.

Dwell time. There have been a number of studies that have examined the dwell time (or length of time the catheter is in use) and its relationship to risk of developing a CLABSI. The literature in this area was mixed; with some that showed a clear association between increased dwell time and increased risk of CLABSI and others that showed a less clear association or no association at all. De Brito et al. (2010) showed a significant risk for infection in PICC lines in place longer than 16 days and umbilical lines in place longer than four days. Hsu et al. (2010) obtained similar results with an increased risk of CLABSI with PICC lines that were in place longer than 20 days. Njere et al. (2011) identified dwell time as a significant risk for CLABSI with a PICC at nine days dwell time with a three times higher risk of infection.

There were also studies that showed a less definitive relationship between dwell time and CLABSI risk. Sengupta et al. (2010) hypothesized that the risk of CLABSI would increase in patients with PICC lines as the dwell time increased. They found that from days 1-18 the risk of infection increased, then from days 19-35 this trend reversed, and finally, if a PICC line was in

place for great than 35 days, the risk of CLABSI increased by 33% per day. Zingg et al. (2011) found that the risk of a CLABSI was highest at less than seven days for both a PICC line and a UVC; however, after seven days the PICC line was less likely to become infected, possibly attributed to antibiotic therapy.

Finally, there were studies that showed that dwell time did not increase the risk of CLABSI and that the risk may have actually had an inverse relationship with dwell time. In a retrospective cohort study of 882 infants, Smith et al. (2008) examined the risk of infection associated with PICC line dwell time. They demonstrated that the longer a catheter was in place, the risk of a CLABSI decreased. They hypothesized that it was because the infant experienced growth and maturation while the catheter was in place and thus had a more mature immune and skin system making them less susceptible to infection overall. Although this study contradicted a large number of other studies, it was done on a large cohort of infants and looked at all gestational ages.

Site of insertion. The location of PICC line insertion, specifically upper extremity or lower extremity, was also identified in the literature as a risk factor. Njere et al. (2011) showed no difference in risk between upper and lower extremity placement. Hsu et al. (2010) showed lower extremity placement, specifically femoral placement, had a higher risk of infection, possibly due to its proximity to the diaper area.

Total parenteral nutrition. The use of TPN was another area of risk mentioned in the literature. Holmes et al. (2008) conducted a study comparing four intrinsic and seven extrinsic risk factors to the presence of a BSI to determine which factors increased a neonate's risk for developing a BSI. Several risk factors were found to be significantly associated with a bloodstream infection based on incidence rate ratios (IRR). However, TPN had the highest

association with a IRR of 16.5 (Holmes, et al., 2008). In addition, a large study (2395 infants, over two years, and all gestations) by Perlman et al. (2007) demonstrated a significant risk of infection in infants who had a central line and were receiving TPN. The reason of this association was unclear, but further examination of TPN use and CLABSIs should be done because premature and ill neonates depend on TPN to meet their nutritional needs while enteral feedings are being introduced and advanced.

Staff attitudes and actions. There were several risk factors for CLABSI that were directly associated with healthcare providers, such as poor aseptic technique during insertion or handling of a central line, and staff that felt their actions did not predispose or prevent infections (Suresh & Edwards, 2012). Three studies highlighted the challenges of prevention strategies (Kime, Mohsini, Nwankwo, & Turner, 2011; Payne et al., 2012; Suresh & Edwards, 2012). They concluded that a key variable in achieving and maintaining low rates of CLABSIs was whether the staff felt that their actions made a difference in patient outcomes. Payne et al. (2012) accomplished this by making staff aware of the adverse consequences that resulted from nosocomial infections. Even with efforts to keep staff engaged, compliance with central line bundles remained at 80% (Payne et al., 2012). Kime et al. (2011) recognized the need to create a culture change and subsequently incorporated a way for coworkers to hold each other accountable for maintaining sterile technique.

Prevention Strategies

There were a number of articles in the literature that provided an overview of generally accepted strategies for preventing CLABSIs (Graham, 2010; Powers & Wirtschafter, 2010; Suresh & Edwards, 2012). Many of the prevention strategies outlined in these articles used recommendations from both the CDC and the Agency for Healthcare Research and Quality

(AHRQ). These included: educating staff on central lines and proper care; using checklists and bundles for insertion and maintenance; proper hand hygiene; maximum sterile precautions (sterile drape, mask, hat, sterile gloves, and sterile gown) for insertion; scrubbing any access hub for an appropriate length of time before accession; and removing non-essential catheters promptly (AHRQ, 2009; CDC, 2013). Neonatal specific data was also available to support the use of many of these strategies. While individual examination of prevention strategies is beneficial, it is also important to understand that the "bundling" of multiple intervention strategies provide a synergistic effect when used together.

Education. Staff education on the prevention of CLABSIs was one of the most supported prevention strategies highlighted in the literature. This included education on both unit specific CLABSI rates and education about specific prevention strategies. Schwab, Geffers, Bärwolff, Rüden, & Gastmeier (2007) found that participation in a surveillance program which included feedback to staff decreased HAI in neonates by 24% from the first to the third year of participation. Although this study was not specific to CLABSIs it did address BSIs in general. There were also several studies that focused on education surrounding one specific prevention strategy. Sannoh, Clones, Munoz, Montecalvo, & Parvez (2010) concentrated their education efforts on hub care and showed a decrease in CLABSI for all types of central lines. Helder et al. (2010) conducted an observational study comparing hand hygiene rates before and after implementation of an educational program in a NICU in the Netherlands. All staff with patient contact were required to participate in a 30-minute program regarding hand hygiene and the study demonstrated significantly improved hand hygiene compliance after the education (Helder et al., 2010). Yilmaz, Caylan, Aydin, Topbas, and Koksall (2007) conducted a study involving pretests, education, and posttests. Physicians, interns, and registered nurses were given a pretest

regarding knowledge of central lines and CLABSIs. They were then required to participate in an educational program regarding epidemiology, risk factors, etiology, prevention, and treatment. Following the education, the participants were given a posttest which showed higher scores than the pretest. Lobo et al. (2010) examined the difference in providing education to staff comparing a one-time lecture to continuous education, and found one lecture only provided a temporary reduction in CLABSI rates. The continuous education provided a sustained effect on CLABSI rates. Finally, Rogers, Alderice, McCall, Jenkins, and Craig. (2010) showed a 24% decrease in CLABSIs after implementing focused education on hand hygiene. While this reduction was not significant in the context of the study, it was still clinically significant from a LOS, cost, and physical ramifications standpoint.

Standardization using bundles and checklists. Many studies have examined the standardization of insertion, maintenance, and removal of central lines as a prevention strategy. Bizarro et al. (2010) was able to show a decrease in the incidence of CLABSI from 8.4/1000 catheter days to 1.28/1000 catheter days after the implementation of a standardization in care practices. Kime et al. (2011) also showed a decrease in CLABSI to zero after implementation of standardization of care, but this study was limited due to its small sample size of only 71 infants. In another very large study of 55,000 central line days, Schulman et al. (2011) showed a significant reduction in CLABSIs by 67% after implementation of standard bundles and checklists. This study also highlighted that NICUs that had the highest checklist compliance also had the greatest decrease in infections (Schulman et al., 2011). The main limitation of this study was that the 18 NICUs studied did not use uniform checklists.

Maintenance teams. Some sites have had success preventing CLABSIs after implementing central line maintenance teams. The members of the team are the most

experienced and educated on the insertion, maintenance, and removal of central lines, thereby reducing the possibility of variation from the standard of care. Taylor et al. (2011) demonstrated a decrease in the incidence of CLABSIs with a dedicated unit PICC team in VLBW infants who had lines in place for fewer than 30 days. Powers and Wirtschafter (2010) also reiterated the effectiveness of a dedicated PICC team, and concluded that with a dedicated team, lines were placed with fewer attempts and with standardized procedures, minimizing variance among technique.

Hub scrub. Evidence has shown that the catheter hub of a central line can be a source of infection. Disinfection of these hubs prior to obtaining access of the central line has been shown to be an important component of CLABSI prevention. Simmons, Bryson, and Porter (2011) used 70% alcohol and friction lasting three, ten, and fifteen seconds prior to accessing the hub. The results of the study showed that friction time had a significant impact on bacterial load on the catheter hub with fifteen seconds as the most effective length of time. Powers and Wirtschafter (2010) also reported fifteen seconds to be the optimal scrub time to reduce bacterial load. They also reported that scrubbing with 70% alcohol or 3% chlorhexidine provided no difference in bacterial reduction, concluding that scrub time was of most significance.

CoNS specific prevention strategies. Because CoNS has been identified as the single most prevalent cause of neonatal CLABSIs there has been much research dedicated to prevention surrounding this organism. Since heparin interferes with the ability of CoNS produced biofilm to adhere to the central line, Birch, Ogden, and Hewson (2010) conducted a randomized controlled trial with 210 infants in which heparin at a concentration of 0.5units/ml was added to the infant's TPN. This study showed a statistically significant reduction in the rate of CLABSI between treated and untreated infants. Hill, Baldwin, Slaughter, Walsh, and Weitkamp (2010)

carried out a randomized trial with 100 infants intending to evaluate the safety of a silver-alginate coated patch at the insertion site of PICC lines. Silver-alginate has antimicrobial properties for certain staphylococcal bacteria (DeRoyal, n.d.). The study found that although the patches were safe for the neonate, they did not alter the microbiology of the CLABSIs that were acquired. Since the purpose of this study was not to see if the patch actually reduced CLABSI but to evaluate the safety of the patch, more research could be done on this intervention.

Another area of research which showed promise for preventing CoNS CLABSIs was the use of targeted medication flushes. Garland et al. (2005) studied 85 infants in a prospective double-blind trial. Forty-two infants received a vancomycin/heparin lock solution into their PICC line two to three times each day for 20 to 60 minutes of dwell time and then it was aspirated back out. Forty-three infants received only the heparin into their PICC line. The vancomycin/heparin group showed a statistically significant reduction in CLABSI when compared to the heparin only group. Filippi et al. (2007) also used a targeted medication flush of a fusidic acid/heparin solution, with a prospective, randomized controlled trial of 103 infants. Fifty were assigned to receive the solution once a day with a dwell time of 60 minutes. Fifty-three infants received a placebo infusion of saline. The solution treated group had significantly lower CLABSI rate compared to the placebo-treated group, 6.2/1000 catheter days versus 24.9/1000 catheters days respectively.

Finally, there has been promising literature about the use of antibiotics around the time of PICC line removal. Removal has been shown to cause CoNS infection, although the exact pathogenesis of this is unknown. The removal of the catheter may cause the biofilm on the catheter surface (which can be colonized with bacteria) to be stripped off, causing a sudden influx of bacteria into the bloodstream. Another hypothesis was that removal of a catheter may

damage the vessel wall leading to inflammation and infection caused by bacteria in the biofilm. Hemels, van den Hoogen, Verboon-Maciolek, Fler, and Krediet (2011) compared an intervention group who received two doses of cefazolin around the time of PICC line removal (one hour before and 12 hours after) with a group who did not. They found a statistically significant reduction in the cases of sepsis following PICC removal with antibiotic treatment. Their study also identified the VLBW infant group as the group most at risk for developing CoNS sepsis, so they recommended treating all VLBW infants with two doses of cefazolin or similar antibiotic around the time of PICC removal.

Summary of the Literature

Each area of this literature review provided knowledge concerning CLABSIs, their risk factors, and prevention. Since increased prematurity and catheter dwell time has been shown to increase the risk of CLABSIs, daily assessment of the continued need for a central line is essential in reducing CLABSIs in neonates. Additionally, a number of therapies hold promise for lowering CLABSIs, including those caused by CoNS, providing an opportunity for further study. Although many studies identified a single specific CLABSI prevention strategy such as education, hub scrub, or the implementation of a PICC team, it is unknown which combination of these techniques is the most effective way to prevent CLABSIs. By comparing the specific strategies employed at several NICUs across the U.S., this study attempted to discover the most effective methods to reduce CLABSIs.

Methods

Research Design and Sample

This was a non-experimental, retrospective, descriptive study. Data was collected from each facility using CLABSI rates reported to the Vermont Oxford Network (VON) and the

infection prevention processes that were in place during the study timeframe. The setting included three level III NICUs identified as NICU-A, NICU-B, and NICU-C and three level II NICUs identified as NICU-D, NICU-E, and NICU-F. There were three hospital sites, one of which had four separate NICUs within the one hospital system (two Level III NICUs and two Level II NICUs). Of the three hospital sites, one was located in the Midwest, one in the Northeast, and one in the Western area of the United States. The sample included all NICU patients who had a central line infection from an umbilical arterial catheter (UAC), an umbilical venous catheter (UVC), a PICC, or a Broviac catheter. The sample was obtained through convenience sampling.

Ethical Considerations

Ethical considerations for this sample included privacy and confidentiality. Since VON data is reported as a group rate for a NICU, individual data was de-identified and unrecognizable. Once the data was obtained it was kept confidential by the researchers. Approval to conduct this project was obtained from the corresponding Institutional Review Boards (IRBs) of the three hospital settings.

Measurement Methods

Quantitative data collected was monthly CLABSI rates per 1000 central line days that each hospital submitted to VON. The incidence of CLABSIs was defined using the standard formula $\frac{\# \text{ of CLABSIs}}{\# \text{ of Catheter Days}} \times 1000$ (CDC, 2012). Qualitative data collected included policies, procedures, and clinical standards for each institution to ascertain the infection prevention practices in place in each NICU. An index of these policies, procedures, and clinical standards was created. When a policy or procedure was initiated or changed the index was updated accordingly with the new information and date of implementation. A specific data collection

tool for this study was not created. Instead, the collection tool currently employed in each unit to report data to VON was utilized.

Data Collection

Each member of the group acted as the researcher for their associated hospital. Quantitative and qualitative data was gathered for the years 2009-2013. Data collection started in the fall of 2013 and was completed in March of 2014.

Results

The study appendix outlines the infection prevention strategies that were in place prior to the study period as well as those implemented during the study period and their date of implementation. Prior to 2009 each unit had multiple infection prevention interventions in place including, but not limited to, hand hygiene campaigns, participation in quality improvement collaboratives, education for staff, and chlorhexidine gluconate (CHG) for skin antisepsis. In the appendix NICUs A, B, E, and F were grouped together as they were subjected to the same infection prevention practices as they are multiple units within the same organization.

Level III NICUs

Figures 1-3 display both quarterly mean CLABSI rates and annual mean CLABSI rates per 1000 central line days (CLDs) for each LIII NICU in the study. Over the 5 year study period, NICU-A had a quarterly mean high CLABSI rate of 3.1 in quarter 3 of 2011, and a low of 0.0. For 10 out of 20 quarters in the study period NICU-A demonstrated a CLABSI rate of 0.0, although these quarters were not consecutive. Only one new infection prevention practice, a Biopatch dressing, was implemented between July of 2009 and February of 2012. During this same time period NICU-A experienced their highest quarterly mean CLABSI rate. The following quarter the CLABSI rate returned to 0.0 and remained there for three consecutive

quarters without additional infection prevention practices implemented. In February of 2012 new infection prevention strategies including sterile central line cap changes every 96 hours, IV tubing changes every 96 hours, masking both caregiver and patient for central line dressing changes, and alternate Biopatch criteria, were instituted. In the following quarters, NICU-A had two quarters with increased CLABSI rates, quarter 3 of 2012 to 0.9, and quarter 3 of 2013 to 2.0. Although they had isolated increases in their monthly CLABSI rate, NICU-A maintained their yearly mean CLABSI rate at 0.5 or less for both 2012 and 2013, and CLABSI rates of 0.0 for 6 of 8 quarters during that same time period.

Although located at a different hospital, NICU-B is in the same organization as NICU-A. Therefore, NICU-B had the same infection prevention strategies prior to 2009 and experienced the same new practices, on the same timeline, as NICU-A. Over the 5 year study period NICU-B had a quarterly mean high CLABSI rate of 3.0 in quarter 4 of 2009, and a quarterly mean low CLABSI rate of 0.0. For 13 out of 20 quarters NICU-B's mean CLABSI rate was 0.0. NICU-B demonstrated 2 time periods of 5 consecutive quarters with CLABSI rates of 0.0, which is equivalent to 2 time periods of more than 1 year CLABSI-free. In February 2012 NICU-B implemented the same infection prevention practices as NICU-A. In the quarters since the implementation of new practices NICU-B had two increases in their quarterly CLABSI rate in quarter 4 of 2012 to 2.8 and quarter 3 of 2013 to 1.4. Despite these 2 increases, NICU-B demonstrated a low annual mean CLABSI rate, maintaining an annual mean CLABSI rate of 0.7 or less for 4 of the 5 years in the study period.

During the 5 year study period NICU-C had a high quarterly mean CLABSI rate of 4.3 in quarters 1, 2, and 4 of 2009 and a low quarterly mean of 0.5 in the first quarter of 2012. The data shows two time periods during which there was the biggest decrease in mean CLABSI rate from

quarter to quarter. The first time period occurred between quarters 2 and 3 of 2010 when the mean CLABSI rate decreased by 2.1. The second occurred between quarter 4 of 2011 and quarter 1 of 2012, when the mean CLABSI rate decreased by 2.6. Prior to the first identified time period with a large quarter to quarter decrease in mean CLABSI rate, NICU-C implemented the following interventions: surveillance of line access and dressing changes, insertion and maintenance video, 15 second hub scrub, insertion and dressing change kits, and MD education about scrub hub. Prior to, and during the second time period, NICU-C introduced the strategies of sterile cap changes using a kit with the provider wearing a mask, cap and tubing changes every 96 hours, CHG tegaderm for central lines, dressing rounds, and hub scrub observations. In the quarters following these two time periods the mean CLABSI rate did increase again, however, the increase was to a lower mean rate. Although NICU-C never reached a quarterly or annual mean CLABSI rate of 0.0, their annual mean has consistently trended downward from a high of 4.1 in 2009 to a low of 1.2 in 2013.

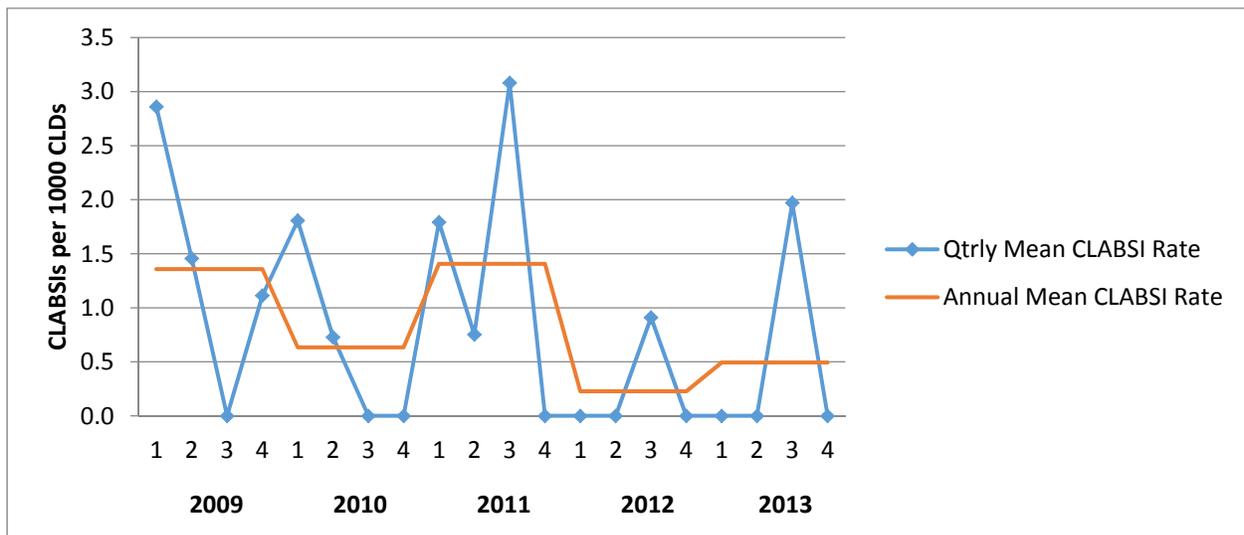


Figure 1. Quarterly and annual mean CLABSI rates for NICU-A.

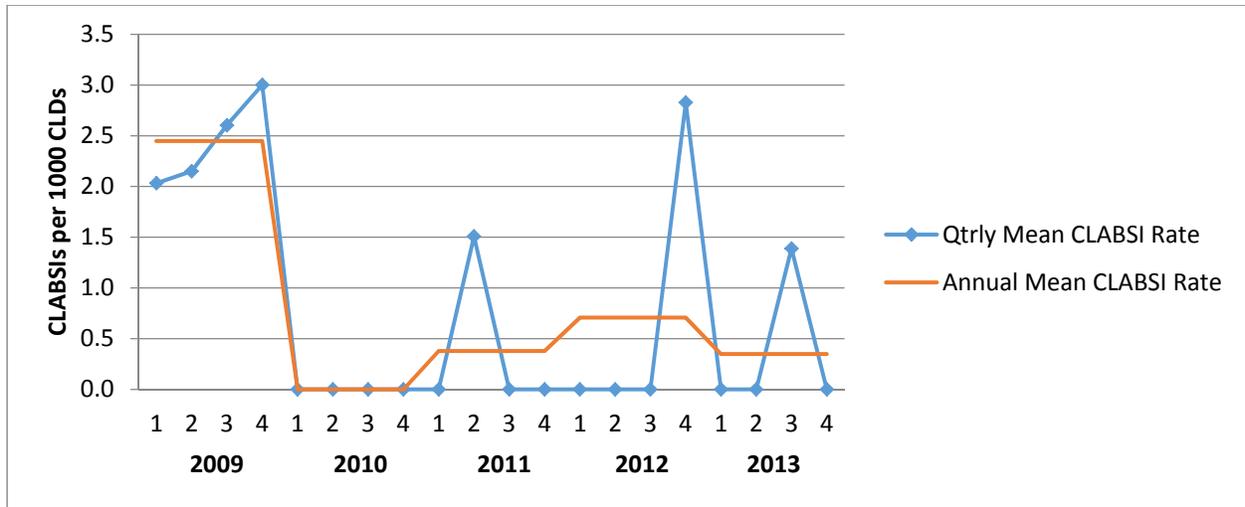


Figure 2. Quarterly and annual mean CLABSIS rates for NICU-B.

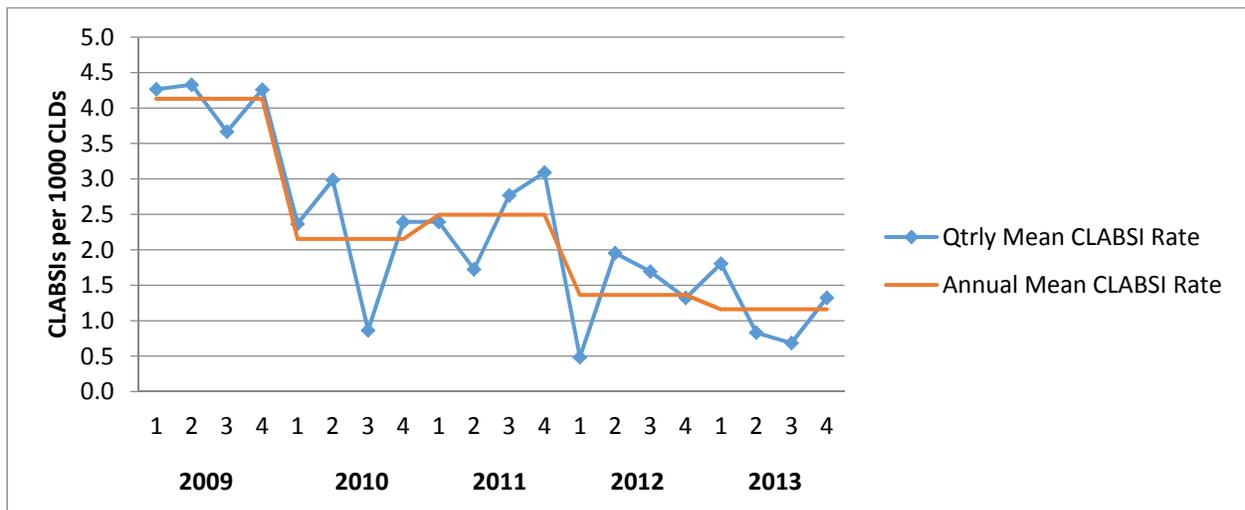


Figure 3. Quarterly and annual mean CLABSIS rates for NICU-C.

Level II NICUs

Figures 4-6 display quarterly and annual mean CLABSIS rates per 1000 CLDs for each LII NICU in the study. For the 5 year study period NICU-D had a quarterly mean high CLABSIS rate of 7.1 in quarter 3 of 2013 and a quarterly mean low of 0.0. For 16 out of 20 quarters NICU-D maintained a quarterly mean CLABSIS rate of 0.0 including a time period of 9 consecutive quarters with a rate of 0.0. This equates to over 2 years CLABSIS free. NICU-D implemented the fewest new infection prevention strategies during the study period. These interventions

included an umbilical line insertion team and a central line insertion practices (CLIP) form introduced in November of 2010 and the use of Curores® caps in August of 2013. In the quarter immediately following introduction of the umbilical line team and the CLIP form NICU-D experienced a spike in their mean CLABSI rate to 3.6, however, the following quarter the mean returned to 0.0 and remained there for 8 more quarters. NICU-D also experienced a spike in the quarterly mean CLABSI rate around the implementation of Curores® caps. After peaking at a rate of 7.1 the rate decreased the following quarter to 2.5, at which time the study period ended. Despite a historically low annual mean CLABSI rate (0.0-1.1) NICU-D had their highest annual CLABSI rate in the final year of the study at 2.4.

NICU-E, as part of the same organization as NICU-A and NICU-B, also operated under same the infection prevention strategies. NICU-E had data available for 2010-2013 only. For the 4 years for which we had data NICU-E had a quarterly mean high CLABSI rate of 4.4 both in quarter 3 of 2012 and quarter 2 of 2013 and a quarterly mean low of 0.0. For 11 out of 16 quarters NICU-E had a quarterly mean CLABSI rate of 0.0 including a 5 quarter consecutive time period when they were CLABSI free. Following the spike in CLABSI rate during quarter 3 of 2012, the rate returned to 0.0 the next quarter and remained there for 2 more quarters. The mean CLABSI rate after the second spike to 4.4 in quarter 2 of 2013 decreased to 3.9 in the next quarter, at which time the study period ended. Neither spike was close in time period to a practice change. NICU-E ended 2013 with an annual mean CLABSI rate higher than the previous 3 years.

NICU-F is the unit with the least amount of data having only started reporting their CLABSI rates in quarter 3 of 2012. Although data is limited, they have maintained both a quarterly and annual mean CLABSI rate of 0.0 for 6 consecutive quarters, which equates to a

year and a half CLABSI free. As part of the same organization as NICUs A, B, and E, NICU-F implemented the same infection prevention practices before and during the study period.

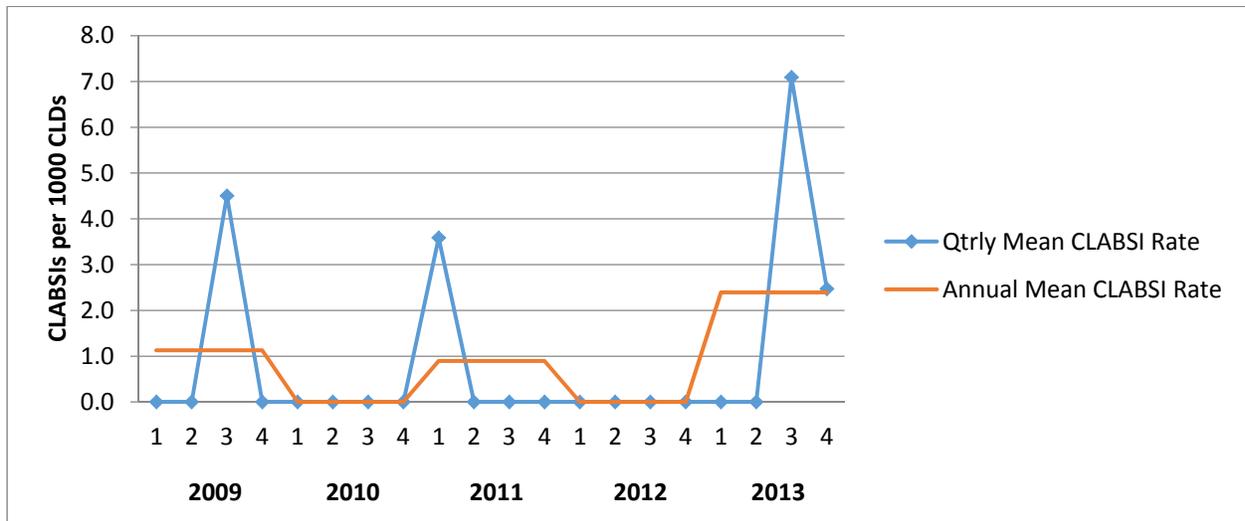


Figure 4. Quarterly and annual mean CLABSI rates for NICU-D.

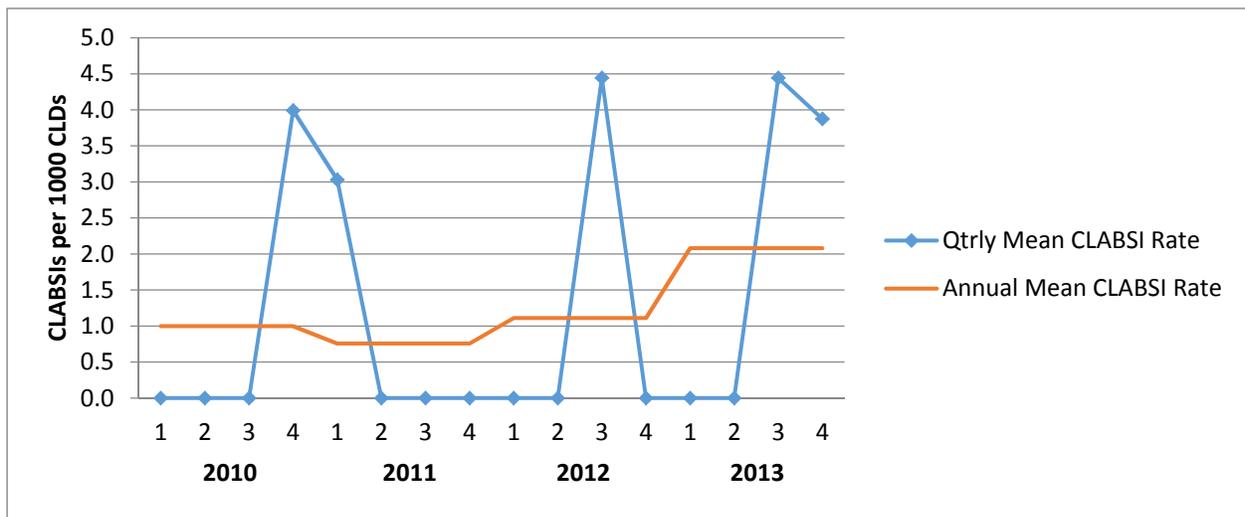


Figure 5. Quarterly and annual mean CLABSI rates for NICU-E.

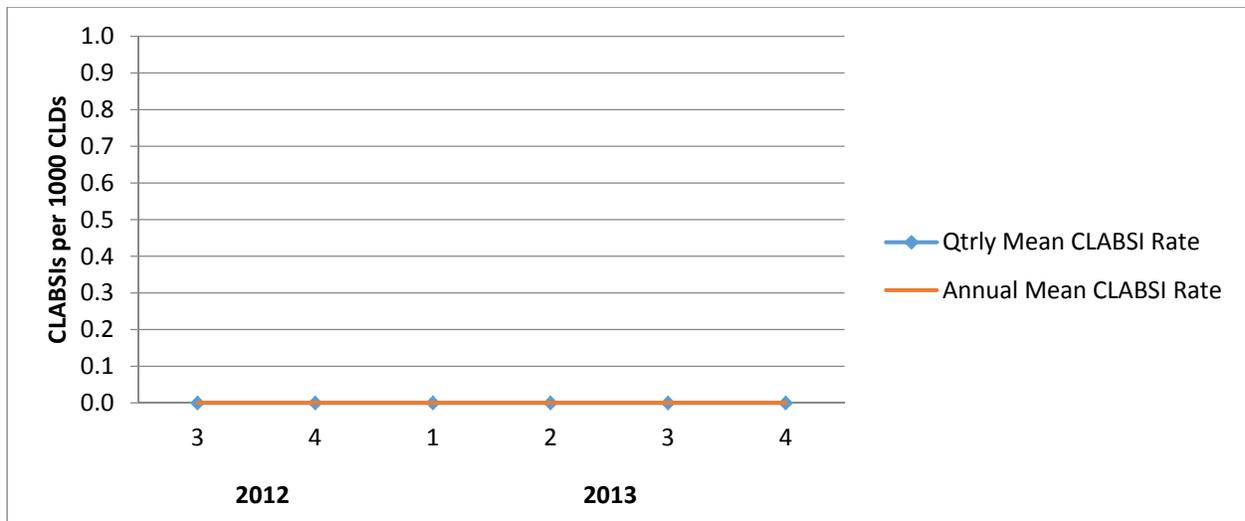


Figure 6. Quarterly and annual mean CLABSI rates for NICU-F.

Discussion

Implications for Nursing Practice

Many factors are important in the prevention of CLABSIs, but due to the need for extended IV nutrition and medications in our NICU population, nursing infection prevention strategies must be utilized when central lines are in use. This retrospective study provided evidence that implementing bundles of evidence-based infection prevention practices and education does reduce CLABSIs in NICUs.

All of the NICUs studied had in place, or implemented in the study period, various infection prevention strategies such as sterile tubing changes, hand and hub hygiene practices, unit wide education, or changes in central line dressing/surveillance practices and infant bathing practices (see Appendix). The CLABSI rates in the level III NICUs dropped following multiple changes in their infection prevention strategies. This was also seen in one of the level II NICUs where the data showed a return to minimal CLABSI rates, following a spike, when a practice change was implemented. The rate decreases may be due to the infection prevention strategies

themselves, as well as an increased awareness and attention to how the central lines were accessed and maintained by nursing staff.

The differences noted in CLABSI rates between level II and level III NICUs is also important to note. These differences were most likely due to the acuity of the patients. Level II NICUs typically care for babies of greater gestational age and less serious conditions; therefore, decreasing the days of intravenous nutrition and medication. While effective infection prevention strategies remain important in all units where central line insertion and maintenance is practiced, birth weight and gestational age, along with dwell time, continue to significantly impact CLABSI rates.

The findings of our study demonstrated that there may be a relationship between multifaceted intervention bundles and reduced CLABSIs. Not only were decreased infection rates demonstrated after implementation of interventions, but the NICUs were able to show sustained results over time, providing further evidence that CLABSIs are preventable. Diligent attention to central line placement and maintenance practices can be a driving force in preventing infection.

Limitations

In analyzing this data it was important to note that all the institutions had robust infection prevention strategies in place prior to the study period, giving the units low initial CLABSI rates. Secondly, we did not independently validate the recorded CLABSIs, and reporting bias from each institution could have influenced the reported results. Also, the data collection tool used in this study was the current tool in place at each facility, thereby creating the possibility of a gap in consistency and accuracy of the data collected. These limitations, however, should be mitigated by the fact that the data reported to the Vermont Oxford Network is standardized across

participating institutions. Another limitation of this study was the implementation of multiple infection prevention interventions simultaneously or within the same year in a given unit, making it impossible to determine which specific intervention preceded the rate decreases, but supporting the effective use of multifaceted infection prevention bundles. Another limitation was the inability to separate neonates who had a central line placed at a referring facility in the data pool. There was no control or knowledge of quality control measures used by providers when inserting central lines at a facility outside the sample population, so it is unknown if this factor contributed to a NICU's CLABSI rate. Comparably, there was no way to separate neonates who had a central line and were also on ECMO (extracorporeal membrane oxygenation). These infants may have had ECMO cannulas in place, which are considered central lines. In many institutions, ECMO cannulas are usually not treated the same as central lines in terms of care and maintenance, so there was no way of knowing if a CLABSI was associated with an ECMO cannula. However, the number of infants on ECMO should comprise only a small percentage of our sample.

Conclusion

Following our extensive review of the literature and exploration of the problem, we know that CLABSIs are a genuine threat to the life of a neonate. Our tolerance countrywide should be a rate of zero CLABSIs in the NICU. Numerous strides have been made in research regarding prevention strategies; however, there is still more research needed. This study added to the current research by defining more explicitly best practice for care of central lines, and how we can use what we already know to move towards total prevention of CLABSIs in the NICU.

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Appendix

Infection prevention practices in place pre-2009 and implemented during study period.

DATE	NICU-A, NICU-B, NICU-E, NICU-F	NICU-C	NICU-D
Pre-2009	Formation of an infection prevention team; hand hygiene campaign; hand hygiene audit; "smart site" hubs; publication of CLABSI rates in the NICU; emphasize enteral over parenteral nutrition; gloves with all patient contact; participation in quality improvement collaboratives through VON; 30 second CHG hub scrub; central line insertion and maintenance bundles, compliance audits, with shared with staff; CHG for skin antisepsis in infants \geq 26 weeks; 4 hours infection prevention education for nursing; preparation of parenteral nutrition under laminar flow hood by pharmacy for infants with a birth weight < 1000 g.; organizational goal of decreasing (BSIs).	NICU in Institute for Healthcare Improvement collaborative; Insertion and maintenance bundle; CHG for site preparation and dressing changes; site visits to high performers in infection prevention; dressing change carts; BSI Advisory/Clinical Champions/Communication Campaign; BSI elimination website; dressing change observation tools; dressing change learning link.	Closed tubing system; PICC team; tubing changes every 72 hours; lipid changes every 24 hours.
March-2009		Surveillance of line access and dressing changes.	
April-2009		Insertion and maintenance video.	
June-2009		15 second scrub hub.	
July-2009	Biopatch dressings for Broviac/femoral lines in infants term gestation or \geq 36 weeks CGA.		
November-2009		Insertion and dressing change kits.	
February-2010		MD education about scrub hub.	
October-2010		CLABSI analytics on the internet.	
November-2010			Umbilical line insertion team; Central Line Insertion Practices (CLIP) form.
January-2011		New dressing change kit; new HH program; HAI video;	
March-2011		HH reports.	
April-2011		Daily baths for infants with central lines (< 36 weeks CGA = sage bath; > 36 weeks CGA = CHG bath).	
May-2011		HH learning link.	

Appendix continued

DATE	NICU-A, NICU-B, NICU-E, NICU-F	NICU-C	NICU-D
August-2011		VAS team begins central venous catheter (CVC) dressing rounds and changes in NICU	
September-2011		HH, sterile glove,s and mask when hub is open for cap change; cap change kit introduced; HH and hub scrub at connection sites; cap and tubing change every 96 hr	
October-2011		CHG Tegaderm for central lines.	
November-2011		Hub scrub observations initiated in NIICU.	
January-2012		CLABSI Reduction huddle with NICU; Screensavers highlighting CVC practice guidelines launched; Unit-specific monthly process compliance reports to CLABSI committees, unit champions, Brown Bag Group, and Unit Leader Partners.	
February-2012	Central line cap changes every 96 hours and done under sterile technique; IV fluid tubing changes every 96 hours; dressing changes done with mask on caregivers; Biopatch criteria altered for NICU (CGA ≥ 36 weeks; 24 hours post-insertion on Broviacs, after insertion on subclavian/femoral lines unless oozing, at the provider discretion on internal jugular lines).	NICU CVC rounds by unit nursing leadership 3 times weekly begun.	
April-2012	New HH campaign.		
August-2012		Curos® caps implemented.	
August-2013			Curos® caps on access ports and hubs.