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REVIEW ARTICLE

Evidence-based approach to preventing central line-associated bloodstream infection in the NICU

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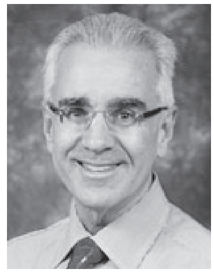

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ABSTRACT

Aim: To review care practices and methods of implementation that reduce the risk of central line-associated bloodstream infection (CLABSI).

Methods: Medical and quality improvement-oriented literature was reviewed.

Results: Although effective catheter practices, equipment and staff training methods are available to reduce CLABSI, their implementation is often difficult.

Conclusion: A successful CLABSI reduction programme requires not only identification of best practices but also understanding of the specific context or unit culture into which they will be introduced.

INTRODUCTION

Hospital acquired infection (HAI), including central line-associated bloodstream infection (CLABSI), is a major cause of mortality, prolonged hospitalization and hospital costs for neonatal intensive care (NICU) patients. For very low birth weight (VLBW) infants, one or more episodes of HAI sharply increase the risk of neurodevelopmental impairment at 18–22 months of age (1). CLABSI is estimated to cause up to 70% of all hospital acquired bloodstream infections in preterm infants (2). Concern for CLABSI has been present since the introduction of long-line silastic central venous catheters in 1983 to provide total parenteral nutrition to neonates (3). Today, central venous catheters are essential in providing modern NICU care, with central catheter utilization rates exceeding 25% of patient days in many NICUs (4). Long thought to be an unavoidable complication of maintaining central venous access in critically ill newborns, CLABSI has been shown to be largely preventable (4). Recent studies have identified

Key Notes

Central line-associated bloodstream infection (CLABSI) is a preventable complication of central venous catheter use. Catheter practices, equipment and staff training methods that are effective in reducing CLABSI are available. A successful intervention to reduce CLABSI requires not only identification and training in use of best practices for central venous catheter insertion and care but also an understanding of the specific context or unit culture into which those practices will be introduced.

individual catheter care practices and bundles of practices that, when used reliably, can dramatically reduce the risk of CLABSI. The purpose of this review is to discuss catheter insertion and maintenance practices that reduce the risk of CLABSI and to discuss recent data on how to reliably introduce these practices into routine clinical care.

CLABSI RISK FACTORS

Clinical practices to prevent CLABSI are driven by the pathogenesis of the disease. In adults, CLABSI prevention interventions have predominantly focused on sterile catheter insertion. In a statewide quality improvement project, a bundle of five evidence-based catheter practices identified as having the greatest effect on the rate of catheter-related bloodstream infection was implemented in 108 Intensive Care Units in Michigan. Four catheter insertion practices, hand washing, full-barrier precautions, cleaning the skin with chlorhexidine and avoiding the femoral site combined with timely removal of the catheter, resulted in a significant reduction in CLABSIs from 7.7 to 1.4 per 1000 catheter days (5).

In neonates, CLABSI prevention efforts must emphasize both sterile insertion techniques and rigorous attention to ongoing catheter care. In a study of independent risk factors for CLABSI in NICU patients, catheter hub colonization was the strongest predictor of subsequent CLABSI followed by exit site colonization, weight <1 kg, postnatal age >7 days and days of total parenteral nutrition (6). Overall, Garland et al. (7) estimate that up to 67% of CLABSIs in NICU patients is attributable to luminal care of the catheter rather than to care of the catheter site or extraluminal colonization.

CLABSI DEFINITION

The diagnosis of CLABSI in neonates can be difficult because the most common organisms causing CLABSI in this age group are normal skin flora, which may be considered bacterial culture contaminants in many clinical settings. Studies in neonates suggest that as many as 33–50% of positive blood cultures with CONS are contaminants (8). In an effort to improve the specificity of the CLABSI diagnosis, the US Centers for Disease Control in 2008 changed the CLABSI definition. Whereas the definition of CLABSI was unchanged for patients with a blood stream infection with a recognized bacterial pathogen occurring after 3 days of age, the 2008 CDC diagnostic criteria for CLABSI with a potential bacterial skin contaminant became more restrictive. Prior to 2008, one positive blood culture yielding a normal skin contaminant (e.g. *S. epidermidis*) treated with antibiotic therapy was considered a CLABSI. Beginning in 2008, the definition of CLABSI with an organism that is potentially a skin contaminant required 'two or more positive blood cultures … drawn on separate occasions' (9,10). The definition change has caused CLABSI rates to decrease, based solely on definitional changes, by at least one-third (4). The updated definition of CLABSI is important to consider when interpreting study results from different time periods.

BEST PRACTICE SELECTION AND IMPLEMENTATION – ESSENTIAL PARTNERS IN A SUCCESSFUL CLABSI REDUCTION INTERVENTION

A successful intervention to reduce CLABSI requires both selection of clinical practices and equipment that have the potential to succeed and implementation of those practices by the clinical team in a reliable way over time. Experimental study designs, such as randomized clinical trials, are useful in determining the efficacy of care practices and equipment to prevent CLABSI. In contrast, implementation of these best practices and clinical interventions into individual NICUs requires an understanding of the unit's unique culture, knowledge and experiential background. Although the clinical practices, equipment and staff training necessary to perform the intervention are essential and often receive the greatest attention, it is frequently the reliable implementation of those practices into daily routine clinical care that proves to be the most difficult.

SELECTION OF BEST PRACTICES

A growing body of literature has identified 'best practices' to prevent CLABSI in neonates. These practices can be introduced singly or as a group or bundle of practices (11). CLABSI prevention is a complex process that may fail at any one of many steps, from lack of sterility during catheter insertion or compromise of the catheter exit site from poor dressing care to contamination of the catheter hub or intravenous (IV) tubing during fluid changes. Hence, use of multi-faceted practice bundles designed to target improved care at multiple steps of the complex process is intuitive. Although there is now ample literature supporting the use of bundles, there are few data comparing interventions of single vs. bundles of care practices (5,11,12). Nonetheless, with the preponderance of evidence supporting their use, bundled care practices have become a common strategy to reduce CLABSI.

Several reviews of best care practices to prevent CLABSI are available and are summarized in Table 1. The efficacy of these practices has been shown individually and in multifaceted care bundles. Because some of the catheter care practices listed in Table 1 target the same work flow process (e.g. buddy system and team-based catheter care), an effective CLABSI bundle need not include each practice element.

Chlorhexidine gluconate (CHG) merits additional discussion. In neonates, CHG has been shown to be superior to povidone iodine in achieving topical antisepsis and preventing catheter tip colonization (13). However, concerns regarding the safety of CHG in neonates have been raised. Some trials, though not all, have shown an increased incidence of dermatitis with CHG at the catheter insertion site. Garland et al. (14) showed elevated blood levels of CHG following its use for skin antisepsis, reflecting cutaneous absorption of CHG through the skin of preterm neonates.

Table 1 Evidence-based catheter care practices

Catheter insertion	Evidence level
Establish a central line kit or cart to consolidate all items necessary for the procedure (25).	IB
Perform hand hygiene with hospital-approved alcohol-based product or antiseptic-containing soap before and after palpating insertion sites and before and after inserting central line (26–28).	IA
Use maximal barrier precautions (including: sterile gown, sterile gloves, surgical mask, hat and large sterile drape) (26,29).	IA
Disinfect skin with appropriate antiseptic (for example, 2% chlorhexidine, 70% alcohol) before catheter insertion (26,30,31)	IA
Use either a sterile transparent semi-permeable dressing or sterile gauze to cover the insertion site (32–34).	IA
Use a dedicated team with special training in insertion and maintenance of central lines (35–37).	IB
Catheter maintenance	
Perform hand hygiene with hospital-approved alcohol-based product or antiseptic-containing soap before and after accessing a catheter or changing the dressing (26–28).	IA
Evaluate the catheter insertion site daily for signs of infection and to assess dressing integrity. At a minimum, if the dressing is damp, soiled or loose, change it aseptically and disinfect the skin around the insertion site with an appropriate antiseptic (31,33,38,39).	IB
Develop and use standardized intravenous tubing setup and changes (40).	IB
Maintain aseptic technique when changing IV tubing and when entering the catheter including 'scrub the hub' (7,33,39).	IA
Daily review of catheter necessity with prompt removal when no longer essential (25,26).	IB
Heparin 0.5 U/mL added to Total Parenteral Nutrition (41)	IA
Minimize catheter access ports (42)	IA

Category IA. Strongly recommended and strongly supported by well-designed experimental, clinical or epidemiological studies.
Category IB. Strongly recommended and supported by some studies and strong theoretical rationale.
Centres for Disease Control and Prevention (43).
All elements are derived from level-1 evidence (43).

Moreover, the CHG level increased with serial exposures, suggesting delayed clearance. For these reasons, CHG is not approved for skin antisepsis by the FDA in neonates <2 months of age. Despite these concerns, a national survey of neonatology programme directors found that most NICUs use CHG, though often with some restrictions (15).

IMPLEMENTATION OF BEST PRACTICES

Identification of best catheter care practices is only part of the challenge in achieving low CLABSI rates. Implementation of identified best practices into routine daily care in the NICU and sustaining them over time is often the greater challenge, requiring understanding of both individual healthcare provider and organizational behaviour. In their work on 'Realistic Evaluation', Pawson and Tilley (16) suggest that successful implementation of a programme such as CLABSI reduction involves understanding of the context, mechanism and outcome (CMO). They write, 'Programmes are products of the foresight of policy-makers. Their fate though ultimately always depends on the imagination of practitioners and participants. Rarely do these visions fully coincide. Interventions never work indefinitely, in the same way and in all circumstances, or for all people'. In the CMO paradigm, programmes successfully achieve outcomes when they introduce ideas and opportunities ('mechanisms') to organizations in the appropriate social and cultural conditions ('contexts') (16,17). Hence, the implementation of new or standardized practices must be tailored to the specific context or unit culture into which it will be introduced. Because of this, many methods used to implement CLABSI reduction programmes have not been subjected to study with randomized controlled trials. However, there are common threads among methods that have been used successfully in individual NICUs and Collaboratives to introduce new practices, standardize those practices and achieve improvement. Table 2 summarizes mechanisms used in clinical reports to introduce care practices into different clinical and organizational contexts.

Reports from three statewide quality improvement Quality Improvement (QI) Collaboratives targeting reduction in nosocomial or CLABSI are illustrative of common methods used to introduce clinical practices into individual NICUs. In Ohio, Kaplan et al. implemented evidence-based catheter care in 24 individual NICUs using centre-based multidisciplinary teams, face to face and webinar-type learning sessions and reduced by 20% the overall incidence of late-onset infection in infants born at 22–29 weeks of gestation. In California, Wirtschafter et al. used a toolkit supplemented by workshops and webcasts to reduce the rate of nosocomial infections by 14% among VLBW infants admitted to any of the State's 27 NICUs. In New York, Schulman et al. employed standardized, evidence-based central line insertion and maintenance bundles, reinforced with the use of checklists to aid compliance with the bundle, to reduce CLABSI rates by 40% in 18 regional referral NICUs.

Common among all three programmes was an attempt to standardize the delivery of the selected bundle of best practices so that they were carried out consistently among all participating centres. Each of the programmes utilized a rigorous education and training programme through webinars, teleconferences and/or face-to-face meetings. Schulman et al. added use of checklists to supplement the education and training and to aid in assessing compliance with the QI bundle. In all three states, reductions in infection rates were greater in those institutions that more actively participated

Table 2 Quality Improvement (QI) methods to implement care practices

Mechanisms to standardize care practices	Evidence level
Education and Training (2,4,18,22)	1B
Checklists (4)	1B
Dedicated Team or Buddy System (paired providers/nurses) for catheter insertion and maintenance (18,19)	1B
Ensure compliance (evaluation and feedback, practice audits) (22)	1B
Incorporate QI Methodologies	1B
Transformational Strategies (e.g. – Six Sigma)(20)	1B
Plan–Do–Study–Act–cycles (8,21)	1B
Strategies to Introduce Care Practices Into Individual NICUs (Contexts)	
Involve Leadership – governmental, regional, hospital and unit (22) (2,4,12,21)	1B
Resources (staff time, money, equipment, space, etc.) (2,4,12,21,22)	1B
Create Culture of Safety – Empower nurses to stop procedures if guidelines are not followed (25).	1B
Promote Teamwork and Team Learning	1B
Quality Collaboratives (benchmark performance, share practices, work flow process, strategies to promote change with similar organizations) (2,4,12,21)	1B
Organization-wide awareness of results	1B
Share results among NICU, families, benchmark organization, QI Collaborative, public (2,4,12,21)	
Statistical process control methods, such as run chart, may be useful) (2,22)	
Occurrence investigations (conduct timely and systematic review of undesired outcomes to gain insight for future) (23)	1B

NICU = neonatal intensive care unit.

in education and training or more actively engaged in the use of checklists. Each of the Collaboratives attempted to ensure compliance with the practice bundle through evaluation and feedback with providers and teams. In other reports, use of a Dedicated Team or Buddy System (paired providers/nurses) for catheter insertion and maintenance (18,19) has proven effective in reducing CLABSI rates, likely through greater compliance with standardized care practices that may occur when working in a group.

Transformational QI methods, such as Six Sigma or Plan–Do–Study–Act (PDSA) cycles, are often utilized to introduce change and standardization of care practices to achieve continuous improvement. Although not subjected to randomized controlled trials in medical settings (20), these strategies have proven effective in many QI projects. In the Ohio Collaborative, Kaplan et al. used QI methods, including PDSA cycles, from the Institute for Healthcare Improvement's Breakthrough Series to reduce the incidence of nosocomial sepsis and CLABSI.

Because each individual NICU has a unique social environment and range of talents among available personnel, the programme used to introduce QI into each NICU must also be individualized. The Ohio, California and New York Quality Collaboratives again illustrate common methods used to introduce practice and work flow changes into the unique social environment of individual NICUs. Common among these efforts was identification and reliance on leadership at multiple levels, state government, hospital and NICU. Inclusion of leadership allows resource needs (staff time, money, equipment, space, etc.) to be recognized and addressed (2,4,12,21,22). Leaders or project champions are also essential to focus team members on performance of care practices and to create an atmosphere which expects and rewards improvement and demands accountability of team members. Reliance on staff empowerment authorizing and expecting that any team member must 'stop the procedure' if guidelines are not followed has also been shown to be effective (20).

Perhaps most important among the strategies to introduce care practices into an individual NICU or group of NICUs is the creation of a team identity and the promotion of teamwork and team learning. Methods used by the Ohio, New York and California QI Collaboratives to accomplish this goal included benchmarked performance, learning sessions to share care practices, work flow processes and strategies used by similar centres to promote change (3,11,39,39,42). These Collaboratives also promoted the sense that practice change resulted in success by assuring organization-wide awareness of results as a Collaborative and in each NICU (19,39). In the New York Collaborative, team identity and motivation were promoted by sharing identified, centre-specific data on institutional performance among all participating centres prior to the intervention and as the intervention unfolded. Continued team learning may also be promoted through occurrence investigations, timely and systematic reviews of undesired outcomes that can be used to direct future improvement in practices, methods or implementation (23).

Statistical process control (SPC) methods, such as run charts of centre or Collaborative performance, are useful in presenting results. For run charts to be most informative, they must display data describing a homogeneous system of care. If individual NICU performance appears to differ among centres (i.e. is heterogeneous), presenting aggregate results risks driving misleading inference for individual NICUs. For example, in a report from the California Collaborative, one SPC chart was used to describe overall performance (17). In the New York Collaborative, although the statewide CLABSI rate improved, one NICU had a 66% increase in infection rate.

Will the strategy work in an individual unit or Collaborative? Roger Gomm has offered a checklist that may be used to evaluate whether a strategy that was effective in one setting (e.g. system A) may be effective in another context (e.g. system B). The checklist includes considerations such as 'What resources were used in producing the outcomes (staff time, money, equipment, space) in system A? What resources are available to system B? Has system B got the resources to emulate the practice of system A? If not, would it be feasible or desirable for system B to enhance or redeploy resources?' (16,24).

Although CLABSI can result in mortality and life-long morbidity, NICU professionals increasingly recognize that CLABSI is a preventable adverse event. Recent studies have identified clinical practices, equipment and staff training methods that are effective in reducing CLABSI. However, to reduce CLABSI, identification and selection of best practices must be partnered with reliable implementation into daily routine clinical care. Quality improvement science, whether applied to an individual NICU or a collaborating group of NICUs, provides a framework to understand that successful CLABSI reduction programmes must focus not only on the processes or mechanisms of care but also on the unique personnel and social context of each NICU into which the desired practices are to be introduced.

CONFLICT OF INTEREST AND FUNDING

The authors have no financial or other conflicts of interest to disclose.

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