

# Evaluation and Development of Potentially Better Practices to Prevent Neonatal Nosocomial Bacteremia

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**ABSTRACT.** *Objective.* Six neonatal intensive care units (NICUs) that are members of the Vermont Oxford National Evidence-Based Quality Improvement Collaborative for Neonatology collaborated to reduce infection rates. There were 7 centers in the original focus group, but 1 center left the collaborative after 1 year. The objective of this study was to develop strategies to decrease nosocomial infection rates in NICUs.

*Methods.* The process included a comprehensive literature review, internal practice analyses, benchmark studies, and development of practical experience through rapid-cycle changes, subsequent analysis, and feedback. This process led to 3 summary statements on potentially better practices in handwashing, approach to nosocomial sepsis evaluations, and central venous catheter management.

*Results.* These statements provide a basis for an evidence-based approach to lowering neonatal intensive care unit nosocomial infection rates.

*Conclusions.* The 2-year process also led to changes in the culture and habits of the institutions involved, which should in turn have long-term effects on other aspects of quality improvement. *Pediatrics* 2003;111:e504–e518. URL: <http://www.pediatrics.org/cgi/content/full/111/4/e504>; *nosocomial infection, handwashing, line management, blood cultures, collaborative quality improvement, NIC/Q 2000.*

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ABBREVIATIONS. NICU, neonatal intensive care unit; NI, nosocomial infection; PBPs, potentially better practices; ELBW, extremely low birth weight; VON, Vermont Oxford Network; NIC/Q 2000, Neonatal Intensive Care Quality Improvement Collaborative Year 2000; CONS, coagulase-negative staphylococcus; IV, intravenous; CAT, critically appraised topic; PDSA, plan-do-study-act; CRBSI, catheter-related blood stream infection; VLBW, very low birth weight.

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## KEY POINTS OF ARTICLE

- Six neonatal intensive care units (NICUs) collaborated in developing strategies to decrease nosocomial infection (NI) rates.
- The process included a comprehensive literature

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review, internal process analysis, and benchmark studies.

- Summary statements were developed for potentially better practices (PBPs) in handwashing, nosocomial sepsis evaluation, and central venous catheter management.
- The collaborative, multidisciplinary approach is multifaceted and leads to a more complete analysis than literature review alone.

## APPLYING LESSONS LEARNED TO PRACTICE

- Summary statements from a group of collaborating NICUs provided a basis for evidence-based approaches to lowering infection rates.
- The process of developing summary statements can lead to changes in culture and habits at the participating institutions.
- Benchmarking seemed to offer the best opportunity for determining which specific practice could reduce infection rates.
- Improvement teams should focus on using multiple sources of evidence to develop small changes in practice that can be made safely and tailored to local cultures.

Current perinatal management techniques have resulted in greater survival for extremely low birth weight (ELBW) infants.<sup>1</sup> However, these infants are at risk for severe short- and long-term morbidities associated with prematurity. Complications include nosocomial bacteremia, which is inversely related to gestational age and frequently accompanies other complications (eg, chronic lung disease, necrotizing enterocolitis).<sup>2,3</sup> Most NICUs have established protocols to prevent hospital-acquired sepsis because this complication is associated with longer length of hospital stay, higher mortality, and greater cost of care.<sup>3</sup> Infection control personnel who are responsible for the NICU monitor trends in birth weight or gestational age-specific NI rates, which are then compared with national data (Nosocomial Infection Surveillance System).<sup>4</sup> For institutions participating in the Vermont Oxford Network (VON), outcome data for infants  $\leq 1500$  g birth weight are tracked on an annual basis and compared with data from other institutions or with pooled network data.

In 1998, a group of VON participant institutions began a collaborative effort to develop NICU quality improvement programs, with a completion date of 2

TABLE 1. Suggested PBPs

PBP	Selected References	Highest Class of Evidence (Muir Gray Scale)*
Handwashing†	19, 22, 65	2
Hub care†	7, 13, 15	2
Reducing skin punctures†	49	5
Treatment of suspected sepsis for 48 h only if the blood culture remains negative‡	41	3
Obtaining blood cultures from a central line and a peripheral site‡	31, 59	4
Use of specific products for skin preparation before drawing a blood culture‡	35, 66	2
Drawing at least 1 cc of blood when obtaining a blood culture	39, 67	3
Limitation in duration of percutaneous lines to <21 d	52–54	3
Maintaining skin integrity with emollients	46, 47	2
Use of maximal barrier precautions for insertion of central catheters†	44, 64	1
Reduction in duration of IV lipid use†	50, 51	3
Avoiding contamination of multidose vials	68	5
Preparation of parenteral nutrition and intralipids under a laminar flow hood	9–11	2
Institution of early feeding with breast milk	69, 70	1
Use of phlebotomy team to reduce the incidence of contaminated blood cultures	29, 30	4
Nonreuse of IV devices during single procedure	71	5
Use of a team for insertion, care, and monitoring of central lines	72, 73	5
Limiting the use of postnatal steroids	74, 75	2
Avoiding unnecessary use of H <sub>2</sub> blockers	76, 77	2
Preparing for deep line insertion	78	2

\* Scale is 1 to 5, highest to lowest evidence.<sup>79</sup>

† PBPs agreed on by collaborating institutions.

‡ Combined into single PBP for summary statement.

years; this effort became known as the Neonatal Intensive Care Quality Improvement Collaborative Year 2000 (NIC/Q 2000). The goal was to implement a program of neonatal quality improvements through rapid-cycle changes within the NICU.<sup>5</sup> VON data showed important variations from institution to institution in the rate of neonatal complications, including NIs. Representatives from 6 institutions that had significantly higher rates of NI than others within the VON chose to focus their collaborative efforts on this complication, hoping to lower their rates to levels comparable to those of others. The problem of late-onset nosocomial sepsis seemed to be an appropriate focus for their work. This article summarizes the process that the 6 institutions used to initiate quality improvement changes to reduce nosocomial sepsis and describes the continuous quality improvement changes that resulted at each participating institution.

## METHODS

Each of the 6 institutions was represented by 2 to 5 individuals from the disciplines of medicine, nursing, infection control, respiratory therapy, and pharmacy. Approximately every 6 months, these representatives met to share findings with each other and members of other study groups participating in NIC/Q 2000 project. Members also held conference calls every 1 to 2 months and held numerous discussions via e-mail using a dedicated list-serv.

To begin the process, the group examined the VON reported data on total NIs. The specific focus became bacteremia caused by coagulase-negative staphylococcus (CONS), which was the etiologic agent for 64% of patients with nosocomial bacteremia. The goal was a 50% reduction in CONS bacteremia in infants <1500 g birth weight.\* Group members, with the assistance of a pediatric

infection control expert (D.A.G.), “brainstormed” the topic and identified several areas of care that might be related to risk of infections, including intravenous (IV) line placement and care, nutrition practices, skin care, respiratory care, and handwashing. In addition, noting that although CONS is a frequent cause of late-onset neonatal infection the agent also may be a skin contaminant, the group concluded that incomplete skin preparation, inadequate blood volume for culture, and other factors related to diagnostic accuracy were important to address.

During the ensuing 6 months, members from each institution reviewed the literature on the areas of care identified as related to risk of NI, in addition to searching for other possible factors. The literature was reviewed by each institution using the critically appraised topic (CAT) method,<sup>6</sup> and all institutions shared their findings and discussed the implications. To expedite the process and maximize group agreements, a professional facilitator (Hannah King) was provided by the NIC/Q 2000 project.

As the investigative process began, the habit of change was being instilled in each institution through encouragement to implement those practices that seemed to be justified by published evidence. NICU staff were encouraged to choose changes that were suited to their environment and represented the best opportunity for improvement in their unit. These changes were implemented using the plan-do-study-act (PDSA) model promoted by the NIC/Q 2000 project. Experiences with these changes were shared and with the evidence from the literature served as the basis for selection of an extensive list of clinical practices that could theoretically have an impact on infection rates. Twenty PBPs with evidence-based support from the CAT method were prioritized (Table 1).

## Questionnaires

After these investigations, at the second meeting, the group assessed the possible change areas and developed a questionnaire that focused on skin care, methods of sepsis diagnosis, central line care, and IV lipid use. The questions were to be answered by each of the 6 institutions in the group, detailing attitudes, policies, practice, and outcomes. The institutions were asked to complete the questionnaire with multidisciplinary input and report staff differences in perceptions and practices. Questions sought evidence of approach rather than specific data, and they were designed to be answered with readily available information.

The questionnaire responses were collated and distributed to all 6 institutions to provide a basis for additional discussion. The responses to some questions were uniform and consistent with evidence from the literature. These questions were deemed not helpful in identifying strategies for improvement. In other areas

\*Definition of CONS infection based on VON criteria (VON Database Manual of Operations, 2000) included 1) coagulase-negative staphylococcus recovered after 3 days of age from a blood culture obtained from a central line, a peripheral blood sample, or cerebral spinal fluid; 2) signs of generalized infection; and 3) treatment with 5 days or more of intravenous antibiotics after the cultures were obtained.

with marked variations in practice, such as the timing of the insertion of central lines in ELBW infants, responses were believed to be helpful in identifying PBPs.

The questionnaire also helped each institution to examine better its own practices. Those who used a multidisciplinary approach in answering the questions learned more about their variations in perceptions and practices. Often a practice was found to be different from the unit policy. One institution found that despite a policy of antiseptic use to prepare the skin before line placement, some practitioners were using sterile water alone to place umbilical catheters in ELBW infants. At least 2 institutions made immediate changes in practice from the ideas generated during discussion of the questionnaire. For example, 1 unit learned that other units had a system for delivering IV lipids from the pharmacy that avoided entry into the line. That unit was able to implement this change immediately. Another unit found that some practitioners performed significantly more sepsis evaluations than others. That unit also had 1 of the highest false-positive blood culture rates, suggesting that a more rigorous approach to sepsis evaluations might lower the infection rate.

The questionnaire was then simplified and used during benchmark visits to gather data that could be compared with data from the 6 collaborating units. Because there were apparent variations among the units in the way that sepsis evaluations were completed and lines were managed, the revised questionnaire focused on these aspects of care.

### Benchmark Visits

After refining the list of PBPs and clarifying practices at collaborating institutions, representatives from each institution arranged to visit sites identified as “better performers” in regard to NI. Institutions to be visited had been identified by VON as having NI rates in the lowest quartile for at least 2 years in a row. Specific sites were selected on the basis of 1) proximity, 2) desire to host a visit, 3) willingness to share information, 4) multidisciplinary completion of the preliminary questionnaire, and 5) demonstrated awareness of efforts to reduce risk of NI. Three of 4 institutions contacted were visited.

Before the visits were scheduled, preliminary discussions occurred between team members and key individuals at the benchmark facilities. On the basis of responses to the preliminary questionnaire, additional questions were drafted to be explored at the visit. Multidisciplinary team members were selected for each visit depending on questions being addressed, including physicians, staff nurses, neonatal nurse practitioners, respiratory therapists, pharmacists, epidemiologists, and administrators. The visits usually lasted a day and a half and involved collaborative meetings between members of like disciplines as well as the entire group, nursery walk-throughs, and case management reviews.

Evidence of the implementation of the PBPs identified by the group was observed at each site visited. Additional PBPs were also identified on the basis of reports of staff at the benchmark institution or observations by site visitors. PBPs implemented in at least 2 benchmark sites were considered to be especially important. Some practices that had been discussed as possible PBPs before the benchmark visits seemed to be less important than others to the success of the benchmark units in achieving low infection rates, and they were deemphasized in the group’s final statements. These included use of special handwashing products and emollients, management of IV lipids, and systemic steroid use.

Variation in the implementation of PBPs was evident among the benchmark institutions. For instance, at 1 institution, phlebotomy teams were used to standardize the approach to drawing blood and obtaining blood cultures. At another institution with a limited number of attending physicians and no residents or neonatal nurse practitioners, standard approach to sepsis workups seemed to be facilitated because the number of staff members was small. These observations led to the conclusion that a systematic approach to the workup and diagnosis of sepsis is important in lowering infection rates. In fact, most of the superior-performing sites had specific protocols (eg, barrier precautions during line change) and consistent care plans (eg, sepsis workup criteria) to minimize or manage nosocomial sepsis assessment, emphasizing the importance of a unit-based, organized approach to this problem. In addition, each benchmark site viewed sepsis as a negative occurrence rather than “a rite of passage” for high-risk infants in

the NICU, emphasizing the importance of practitioners’ perceptions of sepsis.

### Rapid-Cycle Improvements

In the literature reviews, internal audits, benchmarking, and discussions, the group used systems thinking to break the overall goal of reducing CONS infections into 3 key categories of care: methods of diagnosing infections, handwashing, and IV line care. Within each of these general categories, specific measurable aims were identified and PBPs were grouped according to which aim they addressed. These aims led to small tests of change, implemented as rapid-cycle improvement projects at each of the 6 institutions (if they had not previously been done). The resulting experience at each institution was reported at group meetings or through the listserv. Results communicated were both qualitative and quantitative, including feasibility or acceptance of a practice by multiple disciplines within the institution.

Table 2 shows the 24 rapid-cycle projects implemented at the 6 institutions. Eleven of the 24 cycles were implemented at >2 institutions. Although the cycles were often similar, results could not be directly compared from one unit to the other because the quantifiable outcomes differed somewhat. (Outcome data depended on the convenience of collection and acceptance by the disciplines involved at each institution, making uniformity difficult to achieve.) These shared experiences made it possible to determine the most meaningful interventions from the broad list initially identified. Fifteen (63%) of the 24 projects were not directly related to the group’s final summary statements, although they were believed to be important facets of the management of NI.

## RESULTS

The 20 PBPs initially generated by the group (Table 1) were prioritized in a collaborative manner, and 8 PBPs were chosen for emphasis (Table 3). To characterize better the relatedness between practices, the group developed broad statements to address larger perspectives, incorporating many of these PBPs. The 3 final summary statements and additional prioritized practices are given below.

### PBPs to Lower Neonatal CONS Nosocomial Bacteremia

*Reducing Line and Line Connections (Hubs) Contamination Will Decrease Risk of Bacterial Entry and Nosocomial Bacteremia*

Line setups should be designed so as to minimize the number of ports/connections. Each port of entry and connector must be viewed as an independent opportunity for line contamination. The intuitive notion that minimizing entry points will reduce opportunities for violating technique is strengthened by a prospective randomized clinical trial in which a significantly higher rate of catheter-related bloodstream infection (CRBSI) events was associated with the use of triple-lumen catheters than with single-lumen catheters.<sup>7</sup> Latex or silicone membrane ports are recommended because they do not require opening to provide access, and they can be cleaned thoroughly before entry. Manufacturers’ representatives have confirmed site visit observations that line setups in NICUs, in contrast to adult ICUs, are highly variable. Standardization of these configurations represents a potential opportunity for improvement.

IV administration sets should be changed at recommended intervals: parenteral solutions containing amino acids every 72 hours; lipid-containing solutions every 24 hours. Access ports may be left on indefinitely. They should be changed in accordance

**TABLE 2.** Rapid-Cycle Projects Implemented by NI Reduction Group

Rapid-Cycle Project	No. of Centers Implementing Projects
Diagnosis	
Obtain 2 blood cultures of 1 cc each during sepsis evaluations	4
Develop an algorithm to discriminate real from contaminated blood culture	4
Decrease number of sepsis evaluations	2
Investigate method of obtaining blood cultures	3
Skin care	
Evaluate number of invasive punctures that infants get in 1 wk	2
Assess multiuse petrolatum ointment as an infection risk	2
Decrease number of routine labs to decrease number of heel sticks	1
Change skin preparation for invasive procedures to 2% chlorhexidine	4
Line hub care	
Develop a tracking system for central line days	1*
Define hub care practices	4
Educate staff regarding new hub care procedures	4
Implement new hub care protocol	4
Decrease number of connections in line setups	3
Adopt 72-h cycle of IV tubing changes	1
Use sterile dressing technique for PICC lines	2*
Use sterile procedures for TPN tubing changes	2
Collect data related to deep line placement, duration, and culture	2*
Use vancomycin in TPN to decrease line sepsis	1
Handwashing	
Improve compliance with handwashing	6
Introduce new soaps, techniques, and staff awareness of handwashing procedures	4
Remove all jewelry from all staff and visitors to NICU	2
Miscellaneous	
Enforce limitation on use of multidose vials	3
Eliminate environmental contaminants	1
Decrease use of systemic steroids	2

PICC indicates peripherally inserted central catheter; TPN, total parenteral nutrition.

\* Additional institution had implemented change before introduction of NIC/Q 2000.

**TABLE 3.** Eight Prioritized PBP

Increased compliance with hand hygiene standards
Improved accuracy of the diagnosis of bacteremia
Reduced line and line connection (hub) bacterial contamination
Maximal barrier precautions for central line placement
Increased use of emollients to improve skin integrity*
Decreased number of skin punctures
Decreased duration of IV lipid infusion
Decreased duration of central venous line use

\* Modified after additional published evidence (see text).

with the manufacturer's recommendations (eg, after obvious breakdown or accumulation of excessive bloody residue). Parenteral nutrition and lipid emulsion changing intervals have been reviewed and commented on previously.<sup>7-11</sup> No studies have specifically addressed the interval for changing access ports. Benchmark NICUs reported that they left them on indefinitely unless they had obvious breakdown or seemed to have accumulated excessive bloody residue (the latter was frequently noted at sites that implemented "closed" systems using "needleless" appliances).

When accessing a latex/silicone membrane port or a connector, the following are considered essential technique: 1) wash hands; 2) establish a sterile workspace, eg, a sterile gauze surface; 3) prepare the access port with alcohol, using sufficient friction and allowing the surface to dry; or 4) prepare all surfaces to be connected, using sufficient friction and allowing the surfaces to dry (unless the connector being used is fresh from its sterile packaging). CAT review

established that the microorganisms found colonizing catheter hubs were frequently the same as those isolated from catheter tips and bloodstream in patients classified as having CRBSI.<sup>12</sup> In addition, programs that used measures for decreasing hub contamination had significantly lower CRBSI rates.<sup>13,14</sup> Salzman et al<sup>15</sup> found that 99% hub decontamination was achieved by mechanical friction, and the remainder of the decontaminating process was accomplished most effectively by the use of 70% alcohol. In vitro evidence suggests that swabbing the inside of a connecting hub with an alcohol swab or applicator decreases hub contamination<sup>15</sup>; however, the group found only occasional indications that the practice is used and had little enthusiasm for recommending this technique without additional study. Observations at benchmark sites showed uniform compliance with the principles of hub care, although they were often so ingrained that they were not even articulated as essential techniques. This is confirmed by the fact that hub care techniques were not noted specifically or assigned the highest priority among the many PBPs described during the initial collaborative improvement project.<sup>16</sup>

Compliance-enhancing measures include continuing efforts to ensure adequate initial training to perform the procedures, provision of adequate supplies for their execution, and ongoing programs to encourage and monitor their implementation. Several reports describe successful programs to reduce CRBSI rates.<sup>14,17,18</sup> Their common features include multidisciplinary

mensional programs that ensure adequate staff training and equipment, ongoing incentives to encourage program compliance, and means to monitor compliance. Site visits to benchmark units reinforced these points: benchmark unit personnel were very much aware of their excellent results and the ways in which their individual efforts to comply with unit line setup/entry procedures contributed to these excellent results. Unit cohesion around these practices was observed to be very high and epitomized implementation of the concept of "unit culture" as a necessary ingredient for successful practice of a care process, especially when that process requires frequent daily repetitions, often for weeks to months, by many different personnel.

#### *Hand Hygiene Is the Primary Means to Limit Potential Colonization and NIs in High-Risk Newborns*

##### *Purpose*

Hands of hospital personnel can transmit organisms that cause NIs.<sup>19</sup> The microflora of skin consists of resident and transient microorganisms. The transient microflora represent recent contaminants, and these can be pathogens acquired from colonized or infected patients. Transient microflora survive only a limited period of time on the hands. The resident microflora survive and multiply on the skin.<sup>20</sup>

Handwashing with soap can remove most transient microflora, because the organisms are superficial. Resident microflora and antimicrobial-resistant bacteria usually are not removed by plain soap but require products that contain antimicrobial agents.<sup>21</sup> Effective handwashing in the intensive care nursery should achieve mechanical removal of transient microflora and chemical removal of resident microflora.

##### *Process*

Hands must be washed before and after contact with the patient, any equipment that comes in contact with the patient, or any contaminated objects in the environment. If gloves have been used, hands should be washed on their removal. Hands should be washed by rigorously rubbing together for at least 10 to 15 seconds with either chlorhexidine gluconate or triclosan handwashing agents.<sup>21</sup> These 2 agents are relatively fast acting and have broad Gram-negative and Gram-positive spectra. Chlorhexidine gluconate has particularly effective residual antimicrobial activity.

Alcohol-based, waterless rubs may be used when patient contact is urgently needed and there is no sink easily available.<sup>22</sup> These products contain 60% to 70% alcohol with emollients to reduce the drying effect of alcohol. Alcohol-based waterless rubs are as effective as handwashing if the hands are not soiled. Enough alcohol-based rub must be placed on the hands to allow 10 to 15 seconds of washing before the product evaporates. Soap and water handwashing is recommended in conjunction with use of waterless rubs. Most product information recommends that hands be washed with soap and water at least after every 10 to 15 uses of alcohol-based rubs to reconstitute the residual soap action against bacteria.

Also, skin irritation and dryness are less, fostering improved hand hygiene compliance.<sup>23</sup>

Scrub brushes do not seem to be more effective than antiseptic soap alone for hand hygiene,<sup>24</sup> and they are no longer recommended for an initial wash. Scrubbing the hands with a brush removes valuable squamous cells that protect the hands. When squamous cells are removed, skin breakdown occurs at a much more rapid pace. The current recommendation for the initial wash in the intensive care nursery is to wash the hands long enough to remove adequately all soil and transient microorganisms from the hands. Vigorously wash hands, paying attention to all surfaces around finger tips and arms to elbows. Nails should be cleaned thoroughly, and no bracelets, watches, or rings should be worn.

Lotions that are compatible with specified handwashing agents are important factors in hand hygiene. Dryness and dermatitis can result from repeated handwashing. These can lead to breaks in the epidermis, where microorganisms can be harbored. Irritation of the skin also leads to decreased compliance with handwashing policy as a result of discomfort when using handwashing agents. Lotions should be easily accessible and used frequently. Lotions that contain petroleum or other oil emollients should be avoided. Petroleum jelly has been shown to be acceptable from a microbiologic point of view, but concerns have been raised about the potential for petroleum-based lotion to weaken latex gloves and cause an increase in permeability. Attention should be paid to the interaction between lotion and soap, because inactivation of the antibacterial properties is possible with the wrong agent.

A recent study of an outbreak of pseudomonas in the NICU suggests that long or artificial nails may increase the microbial load on hands, particularly Gram-negative bacteria.<sup>25</sup> The American Academy of Pediatrics and the American College of Obstetricians and Gynecologists Guidelines for Perinatal Care and the Association of Operating Room Nurses recommend that nails be kept short and artificial nails not be worn.<sup>25,26</sup>

##### *Compliance*

Continuing education, monitoring, reporting, and feedback to staff on behavior and infection surveillance data will improve compliance and effectiveness of handwashing practices.<sup>27,28</sup> Continual vigilance in reminding staff to wash their hands is necessary. Reminders can be education programs, clever signs throughout the nursery, and individual prompting.

Monitoring staff through periodic handwashing assessments is a valuable tool to reinforce the importance of hand hygiene. In this regard, Glo Germ is a useful tool. (Glo Germ is a substance that illuminates in ultraviolet light that is used to demonstrate the efficacy of handwashing and may help with education of staff on appropriate handwashing techniques.) Reporting feedback in the form of handwashing assessment results can remind staff of the value put on hand hygiene and the importance of preventing infection for the at-risk neonate.

Blood cultures should be obtained from 2 peripheral skin punctures or a peripheral skin puncture and a central catheter hub. This conclusion is supported by published articles on the routine use of multiple blood cultures and contamination of blood cultures in adults.<sup>29,30</sup> A contaminated blood culture is often diagnosed when only 1 of 2 cultures is positive, although inconsistent growth could also represent bacteremia with a low concentration of organisms. The use of blood cultures from central catheters is helpful in that it avoids a skin puncture and often helps to determine whether there is a central line infection.<sup>31,32</sup> Results of a recent study suggest that the differential time to positivity (2 hours more) between the catheter blood and the peripheral blood may be a reliable tool for identifying CRBSI.<sup>31</sup> One institution in the group initiated a rapid-cycle improvement project before the PBP was reached. They were able to obtain 2 blood cultures in 64% to 85% of infants, and learned that 1 of 3 to 1 of 2 of all sepsis evaluations yielded a single positive and a single negative blood culture, suggesting contamination. Physicians used this information to decrease the use of antibiotics.

When preparing for blood culture, the site should be cleaned to remove soiling, and the remaining microorganisms on the skin should be chemically killed. Skin preparation may be a 1- or 2-stage procedure involving 10- to 30-second swabbing of skin and allowing the agents to dry.<sup>33,34</sup> Alcohol, povidone iodine, tincture of iodine, and chlorhexidine have been shown to be effective. The quality of skin preparation is believed to be important in reducing contamination of blood cultures. The literature<sup>31</sup> supports rigor in the procedure, and all of the benchmark sites put special or unique emphasis on this process. The procedures done at the benchmark sites differed, but they were performed consistently at each site. There was no consensus on the specific prepping agent to be used. In adult randomized trials, tincture of iodine has been found to be associated with lower contamination rates than povidone iodine.<sup>35</sup> No studies have been done in neonates. There is concern that increased absorption of iodine using tincture of iodine may cause thyroid dysfunction.<sup>36</sup>

A limited number of highly trained individuals will use better and more standardized technique than a large number of variably trained individuals.<sup>29,30,37</sup>

At 2 of the benchmark sites, a limited number of individuals drew blood cultures. In 1 site, the phlebotomists were the attending neonatologists, and in the other they were respiratory therapists. This recommendation, although strongly supported, has not been undertaken by any of the 6 collaborating institutions because implementation involves substantial shift in training, responsibilities, and culture.

Evidence indicates that a minimum volume of 1 mL of blood is required to detect bloodstream infections. The volume of blood drawn should be

documented. In 2 studies, blood cultures were more likely to be positive when at least 1 cc of blood was obtained.<sup>38,39</sup> One of the benchmark sites routinely drew 2 to 4 mL for blood cultures. The recommendation to record the volume of blood culture was the consensus of the group. This information is rarely available, but it could be clinically useful.

Treat suspected sepsis for 48 hours only. If the blood culture remains negative, then empiric treatment need only last 48 hours.<sup>40,41</sup> Ancillary tests such as the C-reactive protein<sup>42</sup> and white blood count and immature-to-total neutrophil ratio<sup>43</sup> may be helpful to distinguish a false-positive from a true-positive culture.

#### **Additional PBPs**

The following 5 PBPs were identified by the group. They are listed separately rather than as part of the summary statements because they are more concise and stand alone as individual practices.

#### *Use Maximal Barrier Precautions for Insertion of Central Catheters*

Maximal barrier precautions require the use of sterile cap, mask, gown, gloves, and drape. The rationale for this practice is the reduction of contamination during insertion of an indwelling catheter. The benefits of this approach have been demonstrated in prospective randomized trials with adult critical care patients. Raad et al<sup>44</sup> compared maximal barrier precautions with the use of sterile gloves and a small drape only and showed that the rate of infection in the group using only sterile gloves and drape was 3 times that of the group using maximal precautions. In a second randomized controlled trial, Mermel et al<sup>45</sup> studied maximal barrier precautions during the insertion of pulmonary artery catheters and also showed a significant effect of this practice on the reduction of CRBSI. Although the majority of institutions in the group used this practice, at least 1 had not yet adopted it and the practice was not universally implemented, even at the benchmark sites. Given the weight of the evidence, the obvious likelihood of catheter contamination during insertion without maximal barrier precautions and the variability in practice among NICUs, this practice was adopted as a PBP by the group.

#### *Selected Use of Topical Application of Preservative-Free Ointment in Preterm Infants*

The rationale for this practice is that topical emollient therapy decreases dermatitis and fissuring, thus decreasing the entry of bacteria into the bloodstream. Randomized, controlled trials of emollient application have demonstrated improved skin grading scores and decreased numbers of bacteria cultured from the skin.<sup>46,47</sup> However, the practice of routine ointment application remains controversial because a third, more recent randomized trial demonstrated an increase in CONS in preterm infants who received twice-daily petrolatum ointment application.<sup>48</sup> The routine application of emollients may actually increase colonization, with no added benefit for patients who have intact skin. The group consensus is

that emollients have a place in maintaining skin integrity, but routine application for intact skin is unnecessary and the risks may outweigh the benefits.

#### *Decrease the Number of Skin Punctures*

Venipunctures, arterial punctures, IV line starts, and heel sticks provide opportunities for microflora colonizing the skin to be introduced into the bloodstream. It follows that reducing the number of skin punctures should reduce these opportunities. One unpublished retrospective study showed a positive correlation between >5 peripheral IV stick attempts in a 48-hour period and the incidence of bacteremia.<sup>49</sup> One institution in the group decreased the mean number of total sticks per patient per week from 45 to 25 over a 2-month period and decreased bloodstream infections per 1000 line days from 5.7 to 3.1 in the same period.

#### *Reduce the Duration of IV Lipid Use*

Several animal studies suggest that IV lipids are immunosuppressive, are easily contaminated, and support the growth of fungi and bacteria. There are also reports of epidemics and isolated cases related to contamination in human patients. There are 2 retrospective analyses of the relationship of lipids to sepsis in 590 very low birth weight (VLBW) infants, with 83 episodes of bacteremia.<sup>50,51</sup> Of the numerous variables reflecting possible risk for CONS bacteremia, only 2 were shown to be significant by conditional logistic regression, IV lipid use, and surgically or percutaneously placed central catheters.<sup>50</sup> There is evidence of an association between duration of IV lipid use and bacteremia, and the group believed that along with the practices observed at benchmark sites, this evidence was strong enough to recommend limiting the use of IV lipids. Because lipids are a critical part of parenteral nutrition in premature infants, they remain an essential part of early management. Clinicians must balance the risk of infection against the benefit of enhanced caloric intake when deciding how early to curtail the use of IV lipids.

#### *Limit the Number of Days That Percutaneous Deep Lines Are in Place to <21*

Despite measures aimed at reducing the risk of infection from deep lines, the risk cannot be reduced to 0. Several retrospective cohort analyses have shown a correlation between use and duration of deep lines and the incidence of sepsis in neonates.<sup>52–54</sup> In the largest of the studies, by Chathas et al,<sup>52</sup> the duration of silastic deep lines was correlated with the incidence of sepsis, and the authors showed that 21 days was the critical point after which the risk for sepsis became significant. Most VLBW infants will be close to full enteral calories by 21 days of age, so this target of 21 days is feasible and it was therefore chosen by the group as a suggested guideline in overall management of VLBW infants. Other important strategies are necessary to achieve this target, such as early introduction of trophic feeds with breast milk, consistent advancing of feeding volumes, and removal of the deep lines in some infants before full enteral calories are actually reached.

## DISCUSSION

The collaborative multidisciplinary approach taken to determine ways to reduce bacteremia rates was complex and multifaceted and led to a more complete analysis than would have been possible with a simple review of the literature. Participating institutions investigated possible practices related to infection risk, performed detailed literature review with the development of CATs, reviewed personal data and experience, had repeated multidisciplinary discussions, and promoted ongoing collaboration. Each institution performed these activities independently and then shared findings. In some cases, 1 institution would repeat what had previously been done by another. When the groups met for review, similar evidence was presented but from the unique perspectives of each institution.

The process was not intended as a scientific study of the determinants of NI, and individual NICUs did not attempt to determine exactly which factors could be proved to reduce NIs. The focus, rather, was on using multiple sources of evidence to develop small changes in practice that could be made safely and were tailored to the local culture and practice of each institution. The term “potentially better practices” was used to indicate that the suggested changes were not proven as “better,” but there was some evidence in their support. Development of the summary statements (listed in Appendix B) allowed collaborators to weave together the PBP into a broader perspective and to indicate the relative importance, utility, training barriers, and costs of the practice changes. The summary statements also served as an educational tool for introduction of the changes to personnel who were not aware of the details of the studies. Finally, the summary statements conveyed the message that NI would not be resolved by a single intervention or the actions of a single person; rather, a planned set of interventions by many disciplines over an extended time frame would be necessary to reach the ultimate goal. The process that led to the summary statements involved the 4 key habits integral to the NIC/Q 2000 project<sup>5</sup>: 1) the habit of change, 2) the habit of systems thinking, 3) the habit of collaborative learning, and 4) the habit of evidence-based medicine.

#### **Habit for Change**

Personnel at each institution learned the importance of making change in practice to improve outcomes. Helping personnel understand the importance of unit culture was a first step in gaining acceptance of new ideas.<sup>55</sup> The units that were less hierarchical and more collaborative found this easier to accomplish.

#### **Habit for Systems Thinking**

The group learned that the provision of care could be evaluated as many small processes, each of which could be altered with measurable results. It became evident that these small changes could affect the larger process, leading to potentially effective strategies for lowering infection rates.

### Habit for Collaborative Learning

Mechanisms through which centers could share experience and knowledge were critically important in pushing the process forward. The professional facilitator was extremely helpful in focusing and aligning interinstitutional activities. Ongoing communication supported work at each institution not only by providing necessary information but also by providing “team” motivation. At the local level, multidisciplinary teams were formed to plan and implement PDSA cycles. Sharing ideas and experience with other institutions kept the process exciting. Because of geographic diversity and time constraints, listserv e-mail was the most efficient way to communicate among units.

Traditional continuous quality improvement requires focused study of each possible change element, often with long-term data review.<sup>5</sup> Time in those studies is usually measured in months. In this project, the focused PDSA cycles, which were often implemented in weeks, involved multiple small trials, which were important in generating the prioritized list of PBP. Prompt feedback through shared outcome data were important to motivate providers in each unit to keep on track.

### Habit for Evidence-Based Medicine

The practices outlined in the final summary statements have not been proved to lower infection through prospective trials comparing them to alternative strategies. However, the evidence compiled in this project suggests that these practices should be important for lowering NI rates. Practicing evidence-based medicine is an important goal for each of the units participating in this project.<sup>56</sup> However, evidence from randomized clinical trials was not available for many of the medical and nursing practices addressed. Evaluation of the literature on these practices was difficult and often required subjective interpretation. Collaborators relied on one another to achieve an impartial, comprehensive review in developing the CATs, although, in the final analysis, some practices had more literature-based support than others. Collaborating with an infection control expert helped the group to place the neonatal literature review into the larger framework of NI in medical practice. Using data from the literature, the group developed proposed practice changes that could be trialed through PDSA cycles. The results of these cycles then became additional evidence and, for some practices, the best evidence available.

Benchmarking seemed to offer the best opportunity for determining which specific practices would have the greatest impact in reducing infection rates. However, the outcomes of some practices were difficult to interpret because each benchmark site seemed unique, and policies and practices often could not be generalized from one unit to another. Benchmark visits certainly played a large role in prioritizing practices that are important in reducing NIs. However, some PBPs with support from evidence in the literature had not been implemented at the benchmark sites. It is possible that if these PBPs

were initiated, infection rates could be even further improved at the benchmark sites. However, it is also possible that the impact of a PBP may be offset by other practices or attitudes of the unit. The 1 finding common to the benchmark sites was the practitioners’ attitude regarding their roles in lowering NI. Providers at benchmark sites acknowledged that NI rates could be modified by changes in their practices—an attitude that must be developed before real changes can occur.

The PBPs that were developed as part of this collaboration are not surprising in light of general infection control recommendations.<sup>57</sup> However, many frequently referenced infection control guidelines do not give specific evidence for neonatal care.<sup>58,59</sup> Furthermore, although handwashing is a well-established principle of infection control,<sup>57–59</sup> the data suggest that staff often ignore recommendations in this area.<sup>60</sup> In this project, collaborators sought practical ways to enhance effective hand hygiene in the NICU setting. The focus of the PBPs on line care grew out of epidemiologic studies of neonatal infection. Recent reviews concluded that 88% of nosocomial bloodstream infections were associated with umbilical or central venous catheters, and in 56% to 57% of these infections, the etiologic agent was CONS.<sup>4,61</sup> Antisepsis during catheter placement and management have routinely been included in recommendations to prevent NIs.<sup>62,63</sup> The hub care statements in this project give specific guidance for an important aspect of that care. Additional refinements in the recommendations have been made as additional evidence has become available in the literature (references from the years 2000 and 2001 have been added since the completion of the collaborative). This evolution of recommendations suggests the need for continuing review and reassessment of guidelines when additional outcome evidence becomes available.

A multitask approach that involved changing many practices at once—similar to the approach taken by this collaborative—has been successful in preventing line-associated infections in an adult intensive care setting.<sup>18</sup> In that study, the investigators provided clinicians with a detailed protocol for line insertion and tubing changes, including hub care, and additional education regarding handwashing.<sup>18</sup> During the 2-year study period, nosocomial bloodstream infections were decreased by >50%. Sherertz et al<sup>64</sup> also found that a systematic approach to maximal barrier precautions improved compliance and reduced CRBSI.

Review articles addressing neonatal NIs emphasize the difficulty in separating true septicemia or bacteremia from contaminated blood cultures, particularly when the identified organism is a part of normal skin flora.<sup>3</sup> In 1 Australian study of neonatal NIs, 57% of positive cultures were determined to be contaminated.<sup>2</sup> These authors recommended the use of ancillary tools to improve diagnostic accuracy, which is consistent with the PBPs recommended in this project.

The emphasis of this project was on preventing CONS nosocomial neonatal bacteremia, particularly

CRBSI. Because the scope of the collaborative was limited, suggested PBP's did not include possible respiratory sources of infection, which may be related to nosocomial sepsis as well as acquired pneumonia.<sup>4,57</sup> Like IV catheters, endotracheal tubes may facilitate the introduction of microorganisms to a normally sterile area, posing infection risks for the newborn.<sup>4,57,63</sup> Reducing the duration of endotracheal tube use, adhering to sterile precautions with ventilator tubing and during tracheal suctioning, and addressing factors that inhibit pulmonary toilet (sedation, immobilization) are important in preventing respiratory infections.<sup>4,57</sup> Additional PBP's could be developed in these areas.

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## Appendix B

### Summary statements

#### Accuracy of Diagnosis

##### I. Site and Number of Blood Cultures

- A. Two peripheral skin punctures or a peripheral skin puncture and central line hub, if line is present
  - 1. A positive culture of the same organism from both sites confirms catheter-related sepsis.
  - 2. Some sepsis episodes may be associated with a positive culture from only one site, either peripheral or central line hub.
  - 3. Drawing two peripheral cultures may help distinguish false-positive cultures (only one of two positive) from true bloodstream infection (both cultures positive).
  - 4. Repeatedly positive line cultures should lead to a decision to remove the line.

##### II. Prepping for Blood Culture

- A. Purpose of the prepping process
  - 1. Removal of soiling from the skin.
  - 2. Chemical killing of microorganisms remaining on the skin.
- B. Procedure
  - 1. One-stage process for 10-30 seconds, allowing 30 seconds to dry.
  - 2. Two-stage process, using either the same agent or two separate agents, swabbing for 10 seconds, waiting 10 seconds, swabbing again for 10 seconds, and allowing 30 seconds to dry.
- C. Agents
  - 1. No consensus on the superior efficacy of one agent. *Alcohol povidone iodine, tincture of iodine, and chlorhexidine* have all been shown to provide effective and rapid killing, for minimizing contamination of blood cultures.
  - 2. The choice of prepping agent should be based on the balance of efficacy vs potential toxicity from iodine absorption, alcohol absorption/toxicity, and potential loss of skin integrity from the drying effect of some agents.

##### III. Personnel Performing Blood Cultures

- A. A limited number of highly trained individuals will use better and more standardized technique than a large number of variably trained personnel.

##### IV. Volume of Blood for Cultures

- A. Evidence indicates that a minimum volume of 1 ml of blood is required to detect bloodstream infection in neonates.
- B. Volume of blood obtained should be documented in the record.

##### V. Treatment of Suspected Sepsis for 48 Hours Only if the Blood Culture Remains Negative

- A. Evidence from multiple studies supports the fact that 98-100% of pathogens grow out by 48 hr, using rapid detection methods.
- B. Ancillary tests to aid in distinguishing a false-positive from a true-positive culture
  - 1. CRP >5 (positive predictive value for late onset infection of 50%<sup>42</sup>)
  - 2. Neutropenia
  - 3. Immature: total neutrophil ratio >0.2

## **Hub Design and Care**

### **I. Line Setups**

- A. Reduce the number of ports to the minimum required for operation.
- B. Use ports that do not require opening to access (e.g., latex or silicone membrane ports that allow penetration with an access device and can be thoroughly cleaned before each entry).

### **II. Hardware Changes. Recommended intervals for changing elements of the line setup are as follows**

- A. Lipid infusion lines—change every 24 hr.
- B. Parenteral nutrition solutions containing amino acids—change every 72 hr.
- C. Extension lines or ports that are considered part of the central line itself—change in accordance with the manufacturer's recommendations, when they have obvious breakdown or they show excessive bloody residue.

### **III. Prepping**

- A. When entering the line through a latex or silicone membrane port, prep the access port with alcohol, using sufficient friction and allowing the surface to dry.
- B. Prep all surfaces to be connected, unless the connector is being used freshly from sterile packaging. Handwashing and use of a sterile field under the hub are important.
- C. No consensus was reached on the procedure for the inside of hubs. Some units prep with an alcohol swab or applicator, but others are not comfortable doing this. It is recommended that opening of hubs be minimized so as to avoid the potential for introducing organisms into the system.

### **IV. Compliance**

- A. There should be continuing efforts to ensure adequate initial training in these procedures, provision of adequate supplies for their execution, and ongoing programs to encourage and monitor their implementation.

# Handwashing

## I. Introduction

- A. Microflora: The microbial flora of the skin consists of *resident* and *transient* microorganisms. The *transient* microflora represent recent contaminants and can be pathogens acquired from colonized or infected patients. They survive only a limited period of time on the hands. The *resident* microflora survive **and** multiply on the skin.

## II. Purpose

- A. **Mechanical removal of microorganisms.** Handwashing with plain soaps is effective in removing most transient, nonresistant microflora, because the organisms are superficial.
- B. **Chemical removal of microorganisms.** Resident microflora usually are not removed by plain soaps, but can be killed or inhibited with products containing antimicrobial ingredients.
- C. Effective handwashing should achieve both objectives—mechanical removal of transient microflora and chemical removal of resident microflora.

## III. Policies

- A. When to wash: Hands should be washed before and after contact with the patient or **any** equipment that comes in contact with the patient, as well as after removing gloves.
- B. Duration: 10-15 seconds of vigorous rubbing together of all surfaces of lathered hands followed by rinsing in running water. If hands are visibly soiled, more time may be required.
- C. Handwashing agents: The most effective agents for handwashing are *chlorhexidine gluconate (CHG)* and *triclosan*. These two agents are more effective than any other handwashing agents, including povidone iodine, hexachlorophene, and para-chloro-meta-xyleneol, because they have broad gram-negative and gram-positive spectra and are fast-acting; 70% *alcohol* provides the most rapid and greatest reduction in microbial counts on the skin, but is not a good cleaning agent and is thus not recommended in the presence of dirt.
- D. Hand hygiene: Dryness and dermatitis can result from repeated handwashing. These may lead to breaks in the epidermis where microorganisms can be harbored. Irritation of the skin also leads to decreased compliance with handwashing policy due to the discomfort of handwashing agents. Lotions should be used frequently. The lotions must be compatible with the specific handwashing agents used.
- E. Waterless cleaners: Alcohol-based, waterless hand rubs may be useful as an adjunct to handwashing. These products contain 60-70% alcohol, with emollients to reduce the drying effect of alcohol. They are useful when patient contact is urgently needed and a sink is not readily available. These products are as effective as handwashing if the hands are not soiled.
- F. Gloves: Nonsterile gloves are susceptible to contamination by multiple users accessing

the same box of gloves. They are not to be substituted for handwashing. Moreover, hand hygiene must be performed after glove removal because gloves may contaminate hands during removal.

- G. Initial wash: The initial wash before entering the unit should be long enough to accomplish the basic purpose discussed in II A and B. Hands should be washed vigorously with an antimicrobial agent up to the elbows. Brushes are not necessary and may be harmful since they lead to sloughing of skin and contribute to dermatitis. Nails should also be thoroughly cleaned.
- H. Nails: A recent study associated an outbreak of *Pseudomonas* in a NICU with long and artificial nails, and other studies suggest that artificial nails may increase the microbial load on hands, particularly gram-negative bacteria. The AAP and ACOG Guidelines for Perinatal Care and the Association of Operating Room Nurses recommend that nails be kept short and artificial nails not be worn. This group concurs with these recommendations.

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