Evaluation and Development of Potentially Better Practices for the Prevention of Brain Hemorrhage and Ischemic Brain Injury in Very Low Birth Weight Infants

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ABSTRACT. *Objective.* **Neonatal care providers from 5 institutions formed a multidisciplinary focus group with the purpose of identifying potentially better practices, the implementation of which would lead to a reduction in the incidence of intracranial hemorrhage and periventricular leukomalacia in very low birth weight infants.**

Methods. **Practices were analyzed, 4 benchmark neonatal intensive vare units were identified and evaluated, and the literature was assessed using an evidence-based approach. The work was also reviewed by a nationally respected expert.**

Results. **Ten potentially better clinical practices were identified. In addition, variability in cranial ultrasound practice, related to both procedural process and interpretation, was identified as a confounding problem in evaluating quality. Using the same process, potentially better cranial ultrasound practices were also identified.**

Conclusions. **Implementation of these practices will improve clinical outcomes as well as the reliability of sonogram interpretation, the basis for evaluating the quality of the team's work.** *Pediatrics* **2003;111:e489–e496. URL: http://www.pediatrics.org/cgi/content/full/111/4/e489; *intracranial hemorrhage, periventricular leukomalacia, neonates, quality improvement, performance improvement, cranial ultrasonography, collaborative quality improvement, NIC/Q 2000.***

ABBREVIATIONS. NICU, neonatal intensive care unit; PBPs, potentially better practices; ICH, intracranial hemorrhage; PVL, periventricular leukomalacia; VLBW, very low birth weight; NIC/Q 2000, Neonatal Intensive Care Quality Improvement Collaborative Year 2000; Pco_2, partial pressure of carbon dioxide; HF(O)V, high frequency (oscillatory) ventilation; SIMV, synchronized intermittent mandatory ventilation; CAT, critically appraised topic.

KEY POINTS OF ARTICLE

- Outcomes at benchmark institutions were based on the complex interplay of culture and practice factors that are not identifiable through reading of the scientific literature alone.
- Using web-based approaches, it is possible to have an intimate, real-time learning interaction with a neonatal intensive care unit (NICU) that would otherwise not be possible.
- The work involved in this process is intense, and it is important to take time for fun and recognition of the collegial relationships that develop during it.
- There is a great deal of variability, which is not appreciated when comparing outcomes among institutions, in how neonatal cranial sonography is performed and interpreted.

APPLYING LESSONS LEARNED TO PRACTICE

- A change principle underlying several of the potentially better practices (PBPs) is the importance of avoiding rapid fluctuations in arterial and venous blood pressure and thus intracranial pressure and cerebral blood flow.
- Postnatal dexamethasone should be used very cautiously, if at all.
- Postnatal indomethacin is of unclear value related to the effect on long-term neurodevelopmental outcome and should be considered for subpopulations at higher risk for brain injury.
- Perinatal care management for this high-risk group should be intimately directed and provided by the most knowledgeable, experienced, and capable providers in all disciplines.

Intracranial hemorrhage (ICH) and cystic periventricular leukomalacia (PVL) are 2 of the most devastating outcomes for very low birth weight (VLBW) infants, with significant impact on both survival and neurodevelopment. In the Vermont Oxford Network, there is a great deal of variability in ICH and cystic PVL rates, although some institutions consistently perform better than others. There is also a vast literature in this area, an evolving understanding of the pathogenesis of ICH and cystic PVL, and strong opinions regarding their preventability.

In 1999, multidisciplinary teams from 5 NICUs that were participating in the Neonatal Intensive Care Quality Improvement Collaborative Year 2000 (NIC/Q 2000) formed a group to improve their outcomes related to ICH and cystic PVL. Each NICU's team consisted of a neonatologist, a nurse, and an

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advanced practice nurse. Four teams also included a respiratory therapist.

The group, which called itself the Brainy Bunch, established 2 goals: 1) to make measurable improvements in ICH and cystic PVL rates by implementing PBPs and 2) to assess and, if needed, improve the consistency of cranial ultrasound interpretation. The collective goal rates for ICH and cystic PVL were set. The group's rate of ICH in 1997 to 1998 was 23%. The goal was to reduce it to 17% beginning in 2001. The group's rate of cystic PVL in 1997 to 1998 was 4.5%. The goal was to reduce it to 1.4%. These goal rates were equal to or better than the best quartile rates in the Vermont Oxford Network for infants 501 to 1500 g birth weight. Infants that weighed 400 to 500 g were considered unique, and the group elected to look at them separately. The second goal, to assess and improve the consistency of cranial ultrasound interpretation, resulted from the perception that variability in interpretation might be contributing to the variability in rates of ICH and cystic PVL reported to the Vermont Oxford Network. A study, the cranial sonography project, was therefore undertaken to assess that variability.

METHODS

Analysis of Current Practice at Participating Centers

A practice analysis questionnaire was developed through group brainstorming sessions so that the participating centers could compare their current practices with those of the benchmark sites that would be identified later. Five areas were analyzed: antepartum (labor and delivery) care, delivery room resuscitation, medical care in the NICU, developmental care in the NICU, and sonography practices. Demographic information on both the infants and the NICU staff was also sought. Each NICU used the questionnaire to assess its own internal practices and summarized its information. The answers were then collated for all 5 units to compare practices between institutions.

On the basis of the practice analysis, an additional focused data collection was done to assess practices during the first 72 hours after birth. At each institution, infants with grades 3 and 4 ICH and cystic PVL were compared with a control group of infants without sonographic abnormality matched on birth weight and gestational age. Data items included admission temperature, initial partial pressure of carbon dioxide (Pco_2), highest and lowest Pco_2, serum sodium and blood urea nitrogen in the first 72 hours, type of ventilation, presence of pulmonary interstitial emphysema, blood pressure treatment, intravenous fluid rates during the first 3 days, and certain standard Vermont Oxford Network database fields. The last included data related to birth weight and gestation, place of birth (inborn versus outborn), delivery room status (Apgar scores) and resuscitation, type of ventilation (high frequency [oscillatory] ventilation [HF(O)V] or synchronized intermittent mandatory ventilation [SIMV]), and presence of pneumothorax. The data from the units were then combined. There was a significantly high incidence of hypocarbia (Pco_2 <30 mm Hg), hypercarbia (Pco_2 >70 mm Hg), hypernatremia (serum sodium >150 mEq/L [>150 mmol/L]), and azotemia (blood urea nitrogen >30 mg/dL [>10.7 mmol/L]) in the infants with ICH and cystic PVL, compared with the control group.

Identification and Analysis of Benchmark Sites

The Vermont Oxford Network Collaborative Learning Directory and additional information from the network were used to identify possible benchmark sites, and a questionnaire was developed to screen the sites. Screening questions included demographics such as number of admissions per year, percentage of outborn and inborn admissions, other outcome information such as standardized mortality, and ICH and PVL rates over several years. Willingness to participate and share data and an understanding of the reasons for their success were also considered important. The sites were interviewed by telephone or, in the case of a site in New Zealand, by e-mail.

Four benchmark sites were identified. All 4 sites had >75 VLBW admissions per year, had outborn as well as inborn admissions, and had consistent standardized mortality rates as well as rates of ICH and cystic PVL in the top quartile of the network over several years.

All 4 sites shared their data and completed the practice analysis questionnaire initially completed by group members. Visits of 2 of the sites occurred along with a team meeting with a third site that was a member of the NIC/Q 2000 collaborative. Collaboration with the fourth site, in New Zealand, was accomplished through the use of e-mail and videoconferencing. Representatives from each discipline, from all 5 participating institutions, participated in each benchmark visit or discussion.

A χ^2 analysis was done to compare the outcomes of the benchmark NICUs with those of the group members' NICUs, both collectively and individually. This analysis clearly showed that the benchmark sites had significantly better outcomes. No apparent differences in populations were found in terms of antenatal betamethasone, birth weight, gestational age, gender, Apgar score, need for resuscitation, or inborn versus outborn admission. There were also no significant differences in decision making regarding resuscitation of very immature infants.

Through the internal practice analysis and benchmark visits, several notable practice differences were observed. Three of the 4 benchmark sites did not use prophylactic surfactant or early postnatal indomethacin. There were significant differences in blood pressure management. One benchmark site treated only clinical findings of hypotension without concern for actual blood pressure values, whereas 2 other sites treated low blood pressure values aggressively. Fluid management also varied. Developmental care was emphasized at all 4 benchmark sites. The attending neonatologists were actively involved in decision making in the NICU, and there seemed to be an emphasis on consistency of care. One site aggressively evaluated coagulation and attempted to correct abnormalities.

Evidence Levels for PBPs

Initially, the group identified 25 possible PBPs at a brainstorming session. The literature was then reviewed, and the quality of the evidence for each practice was evaluated. When appropriate, the critically appraised topic (CATs) format was used.

The group added 2 evidence levels to the classification scheme adopted by the NIC/Q 2000 collaborative (Table 1): 6) the practice is supported by a causal theory of disease or pathogenesis, and 7) the practice is based on experience or intuition. The possible practices varied widely in evidentiary strength. For example, the evidence for antenatal betamethasone was clearly level 1. In contrast, the evidence of the effectiveness of developmental care came

TABLE 1. Evidence Scheme Modified From the NIC/Q 2000 Evidence Scheme

Level	Criterion
1	Strong evidence from at least 1 systematic review of multiple well-designed randomized controlled trials
2	Strong evidence from at least 1 properly designed randomized controlled trial of appropriate size
3	Evidence from well-designed trials without randomization, including single-group pre-post, cohort, time-series, or matched case-control studies
4	Evidence from well-designed nonexperimental studies preferably from >1 center or research group
5	Opinions of respected authorities based on clinical evidence, descriptive, studies, or reports of expert committees
6	Supported by causal theory of disease or pathogenesis
7	Based on experience or intuition

Levels 1 through 5 adapted from Muir Gray (*Evidence-Based Health Care: How to Make Health Policy and Management Decisions.* New York, NY and London, England: Churchill Livingstone; 1997) by the NIC/Q 2000 Collaborative.

largely from personal observations during the benchmark site visits.

After an initial list was developed, an expert consultant, Dr Jeffrey Perlman, reviewed the team's work and recommended modifications to the list. For instance, Dr Perlman recommended limiting the use of prophylactic indomethacin to a high-risk population, such as infants whose mother had not received antenatal steroids or who had chorioamnionitis.

The Cranial Sonography Project

To assess the quality of sonography practices in member institutions, each NICU selected 10 sonograms; patient and center identifiers were removed and all 50 sonograms were read at each institution by a radiologist dedicated to reading newborn sonograms at that institution. Marked variability in interpretation was noted. The κ value for interreader reliability was only 0.361, and there was complete agreement on the grading of only 7/50 sonograms. For many sonograms, there was also wide variability in the hemorrhage grades assigned.

The sonography practice analysis revealed significant differences in both methods and interpretation. There were differences in the type and generation of machine used. In some units, the radiologist performed the study, whereas in others, the radiologist looked at videotape or cuts taken by a technician.

There was also variability in the definitions for different ICH grades. For example, choroid plexus hemorrhage was considered either grade 1 or grade 2 or outside the current grading system used in the Vermont Oxford Network database. With the latter definition, a infant with a choroid plexus hemorrhage would be reported as "normal." Similarly, there was disagreement about what constitutes a grade 3 ICH.

Variability in sonography practices was noted at benchmark sites as well. At 1 site, the sonograms were performed and interpreted by the neonatologists themselves. At another, neonatologists reviewed the sonograms; if they disagreed with the radiologist, then they reviewed the study together to reach consensus.

Because the sonogram is the basis for neurodevelopmental prognosis for the infant as well as the measure of all improvement work, reliable, believable interpretation is critical. Therefore, the group set the goal of improving consistency in the interpretation of sonograms; specifically, to achieve good to excellent intraobserver and interobserver reliability in ultrasound diagnosis of intracranial abnormalities (hemorrhage, echo densities, ventricular dilatation, PVL), defined as having a κ value >0.75.

Once the initial study and practice analysis were completed, the group and radiologists from each of the 5 institutions worked together to develop PBPs related to brain sonography. The literature was reviewed and assessed for the level of evidence for each of these PBPs, as had been done for the PBPs in clinical care.

RESULTS

PBPs in Clinical Care

Evidence could not be found in the literature for several practices on the original list of 25 PBPs, and they were eliminated. Ultimately, the group identified 10 PBPs. For better defining the scope of care and facilitate analysis, specific recommendations were grouped under the appropriate PBP. Three of these practices (4, 6, and 8) are directed at minimizing blood pressure fluctuations. The PBPs are summarized in Table 2.

Optimize Antenatal Steroid Usage

Administer antenatal betamethasone

The level of evidence is 1[1,2] (see Table 1). Multiple randomized, controlled trials and a meta-analysis have shown that the antenatal use of betamethasone improves intact survival and decreases the risk of intracranial hemorrhage.

Avoid antenatal dexamethasone

The level of evidence is 4.[3] A well-conducted retrospective study has indicated that antenatal dexamethasone is associated with a greater risk of periventricular leukomalacia than antenatal betamethasone.

Optimize Peripartum Management

Encourage delivery in a tertiary center with a NICU

The level of evidence is 3.[4–6] Evidence from multiple studies has shown that outborn or transported infants consistently have higher morbidity and mortality than inborn infants. This includes higher rates of ICH and cystic PVL.

Clinical management of labor and delivery should be done by maternal fetal medicine specialists.

The level of evidence is 7. We were unable to find any literature on this practice, but it was a prominent feature at the best-performing hospitals.

Administer antenatal antibiotics for preterm rupture of membranes

The level of evidence is 1 (weak).[7] Several articles have indicated that chorioamnionitis is a major independent risk factor for ICH/PVL. Antibiotic treatment in these circumstances has been shown to decrease the risk. Unfortunately, the same articles indicate that the concomitant use of glucocorticoids may decrease the effect of the antibiotics.

Make neonatologists and an experienced team responsible for delivery room resuscitation

The level of evidence is 2 (for survival),[8–10] 6 for other outcomes. A large volume of resuscitation literature addresses experience level and retention of neonatal resuscitation skills by residents and family doctors.[11,12] However, the composition of the resuscitation team is not well addressed in any articles. At the 5 participating institutions, the team composition was not well delineated and varied greatly (including nurse, nurse practitioner, resident, respiratory therapist, neonatology fellow, neonatologist in all combinations and at all experience levels). At 1 site in the focus group, a teaching hospital, an extremely high proportion of infants required cardiac compressions and epinephrine during resuscitation. This was attributed to direct management by residents and interns. The other sites routinely had a neonatologist at every high-risk delivery, if possible.

Maintain the infant's body temperature $\geq$36°C

The level of evidence is 6.[13,14] There are no recent studies. However, several older studies indicate that the thermal environment has a significant effect on the outcomes of preterm infants. Research on cooling for brain preservation after asphyxia may provide some light. The participating NICUs have used multiple methods to ensure the thermal stability of infants: chemical heating mattresses, ventilators placed on the transport warmers, delivery room warming, plastic bags, and heated radiograph cassettes.

Maintain cardiorespiratory stability for surfactant administration

The level of evidence is 2[15,16] or 6. Most of the benchmark sites did not use prophylactic surfactant, but ample evidence supports this therapy. The benchmark sites were very good at stabilizing the infants before surfactant. One study[17] indicates that

TABLE 2. Final List of PBPs for Prevention of ICH and Cystic PVL

No.	Practice	Evidence Level†
1	A. Administer antenatal betamethasone	1
	B. Avoid antenatal dexamethasone	4
2	Optimize peripartum management by	
	A. Delivery in a tertiary center with NICU	3
	B. Direct clinical management of labor and delivery by maternal fetal medicine specialists	7
	C. Administering antenatal antibiotics for preterm rupture of membranes	1 (weak in terms of multivariate analysis), 4
	D. Delivery room resuscitation by neonatologists and an experienced team	4 (adequate training), 7
	E. Maintaining the baby's temperature ≥36°C	2, 2 (other outcome = survival), 6
	F. Maintaining cardiorespiratory stability while administering surfactant	2, 6
3	Optimize direct clinical management by neonatologists	4 (other outcomes), 7
4*	Implement measures to minimize pain and stress responses	
	A. Use developmental care	
	1. Reduce environmental noise	3, 4, 6 (other outcomes), 7
	2. Minimize handling	2 (soft statistically), 3
	3. Minimize lighting	7
	B. If needed, judiciously use narcotic sedation (low dose, continuous)	2 (weak randomized, controlled trial as a result of small sample size and wide confidence limits), 5
	C. Avoid early lumbar puncture (group consensus is "early" ≤ 72 h old)	4
5	Use optimal positioning. Maintain neutral head position when turning and positioning the baby with the head of bed elevated 30 degrees	4, 6
6*	In terms of fluid volume treatment of hypotension, there is no evidence demonstrating benefit of using MAP ≥30 rather than MAP ≥estimated gestational age weeks	
	A. Only treat "overt" hypovolemia	2, 3
	B. Without "overt" hypovolemic hypotension, only use up to 2 boluses before inotropes	
	C. Give bolus infusions over ≥30 min	2 (weak, animal and indirect), 3, 6
7	Use postnatal indomethacin judiciously	1, 1
8*	Optimize respiratory management	
	A. Ventilator management using either SIMV or HFV-optimal volume strategy (ie, avoid IMV or HFV-low volume strategy)	1, 2 (evidence does not show advantage of one over the other)
	B. Avoid hypocapnia (group consensus is to keep Pco_2 ≥40)	3 (evidence based on Pco_2 <20)
	C. Avoid routine chest physiotherapy	2 (weak as result of size), 3-, 4
	D. Avoid routine suctioning	
9	Limit sodium bicarbonate use; if given, infuse slowly (group consensus is ≥30 min)	3 (Papille's study used very diluted bicarb over minimum of 5 min)
10	Use postnatal dexamethasone judiciously	
	A. Avoid early postnatal use	2
	B. Avoid prolonged courses (42 d)	2

MAP indicates mean arterial pressure
* Practice is related to desire to minimize blood pressure fluctuations (see worksheet).
† See Table 1 for interpretation of levels.

giving surfactant 10 minutes after birth is better than immediate instillation.

Optimize Direct Clinical Management by Neonatologists

The level of evidence is 4[18] or 7. We were unable to find evidence in the literature to substantiate this PBP, but after observations at all of the benchmark sites, it was believed to be an important practice. Observational evidence on other outcomes also supports this practice.

Implement Measures to Minimize Pain and Stress Responses

Provide developmental care, decrease noise, minimize handling and lighting

The level of evidence is 2, 3, 4, 6 (other outcomes), or 7. Several articles[19–22] have indicated that the evidence is weak. However, developmental care that emphasized these aspects was noted at each benchmark site, and all group NICUs believed that this is an important aspect of care of the VLBW infant.

Use narcotic sedation judiciously

The level of evidence is 2 or 5. The group initially thought that liberal use of narcotic sedation would be found to be detrimental. All 5 participating NICUs used narcotic sedation to various degrees. The evidence found was weak,[23,24] because of small sample size and wide confidence limits.

Avoid early lumbar puncture

The level of evidence is 4. There is evidence[25] that performing a lumbar puncture has adverse effects on heart rate and oxygen saturation. There is also observational evidence of the lack of diagnostic benefit of early lumbar puncture.[26–28] Although there is no direct evidence of neurologic effects, the group consensus was to avoid the procedure in infants younger than 72 hours of age.

Maintain Neutral Head Position When Turning and Positioning the Infant With the Head of the Bed Elevated 30 Degrees

The level of evidence is 4 or 6. Studies[29,30] have shown that turning the infant's head to the side affects jugular venous return and may affect intracranial pressure and cerebral blood flow. The benchmark site with the lowest rate of ICH used this practice.

Optimize Therapy for Hypotension

The relationship of ICH to hypotension or hypertension is not well established, but multiple studies have implicated these as causal factors.[31–33] Multiple definitions of hypotension exist.[34,35] The group also observed varied approaches to the treatment of hypotension at the benchmark hospitals. In general, it was believed that the evidence supported cautious treatment; clinical findings along with standard numeric parameters should be determinants of therapy. In terms of fluid volume treatment of hypotension, there is no evidence demonstrating benefit of using mean arterial pressure ≥30 rather than mean arterial pressure ≥ estimated gestational age (weeks). Although hypertension has also been associated with hemorrhage,[36] the group did not address this with a specific PBP.

Treat only overt hypovolemia such as obvious blood loss from placenta previa, cord rupture, and so forth

The level of evidence is 3 (multiple animal and nonrandomized human studies on shock).

Without overt hypovolemia, use maximum of 2 volume boluses

The level of evidence is 2 (weak, animal and indirect).

Give bolus infusions over >30 minutes

The level of evidence is 3.[37]

Use postnatal indomethacin judiciously

The level of evidence is 1. The work of Fowlie[38] and others revealed that use of prophylactic indomethacin seemed to decrease the incidence of ICH in VLBW infants. However, despite the lack of evidence of harm, there is concern that indomethacin increases the risk of intestinal perforation and renal insufficiency. Recently, the Trial of Indomethacin Prophylaxis in Preterms Study[39] indicated that although infants who are given indomethacin do have less severe hemorrhages, they do not have a better cognitive outcome at 18 months. This PBP has therefore become even more controversial. The expert suggested that perhaps indomethacin be reserved for certain at-risk infants, such as those for whom the mother had not received antenatal betamethasone or had chorioamnionitis, rather than giving it to all infants.

Optimize Respiratory Management

For ventilator management, use either SIMV or HF(O)V with optimal volume strategy

The level of evidence is 1 or 2.[40–42] A large amount of evidence supports the use of SIMV. One study involving the use of HF(O)V showed an increase in the incidence of ICH. However, this study used a different high-frequency ventilator with a fixed inspiratory:expiratory ratio and a low-volume strategy. If this study is removed from consideration, then HF(O)V with optimal-volume strategy is associated with no increase in ICH compared with SIMV. A recently completed but unpublished randomized control trial may more fully answer this question. During 1997 and 1998, the hospitals in this group used HF(O)V extensively, but 2 of the benchmark sites did not use it routinely.

Avoid hypocapnia

The level of evidence is 3.[43,44] The evidence documenting the effects of Pco_2 on cerebral blood flow is plentiful. Evidence of the effects of Pco_2 on ICH consists of 1 small randomized trial, which looked at Pco_2 levels <20 mm Hg. The group consensus was to keep Pco_2 levels ≥40 mm Hg. Large swings in Pco_2 may be detrimental, but no data exist to support this.

Avoid routine chest physiotherapy

The level of evidence is 2, 3, or 4.[45–49] There is evidence of a strong link between chest physiotherapy and ICH in early gestational age infants. The procedure can be devastating, especially in the first 72 hours.

Avoid routine suctioning

The level of evidence is 6.[50–52] No data were found establishing a link between suctioning and ICH. However, it is well documented that changes occur in blood pressure, cerebral blood flow, and intracranial pressure during suctioning. It is logical to think that these changes may be detrimental to the infant, and the group consensus therefore was to eliminate this noxious activity from routine care.

Limit Sodium Bicarbonate Use; if Needed, Give Over 30 Minutes

The level of evidence is 3.

Although the use of bicarbonate for metabolic acidosis is widespread, there is little evidence of its efficacy[53] and a vast body of literature on its side effects.[54] The American Heart Association recognizes only 3 situations in which $NaHCO_3$ is useful: hyperkalemia, urinary bicarbonate loss, and prolonged cardiac arrest.[55] There is substantial evidence that diluting the bicarbonate and infusing it slowly is preferable to rapid concentrated infusions.[56,57] Treatment of the basic problem causing the metabolic acidosis is still the best therapy.[58]

Use Postnatal Dexamethasone Judiciously

Avoid early use of postnatal dexamethasone

The level of evidence is 2. Several studies have indicated that the early (less than day of life 14) use of postnatal dexamethasone is associated with a higher incidence of cerebral palsy or significant neurodevelopmental handicap.[59,60] Another study has shown increased risk of ICH.[61]

Avoid prolonged courses of postnatal dexamethasone

The level of evidence is 2. In a recent randomized trial of treatment of chronic lung disease, long-term neurologic complications were significantly worse with prolonged dexamethasone treatment.[62]

PBPs Related to Brain Sonography

On the basis of the practice analysis and interactions with the radiologists at the 5 participating NICUs, 5 PBPs related to sonography practices were identified. The level of evidence is 3, 5, or 7.

1. The studies should be performed by a consistent, small number of well-trained radiologists or radiologic technicians.

2. The most accurate interpretation is based on real-time or video evaluation. A standardized set of image cuts based on an agreed on "gold standard" is also important.
3. An agreed-on system of interpretation, consisting of both text and an image set, should be used.
4. Serial studies should be performed to optimize correct diagnosis of choroid plexus and germinal matrix lesions.
5. Performance and interpretation of cranial sonography should be evaluated periodically.

Only a few published studies have looked at these issues.[63–69] For the most part, they have compared sonography findings with computed tomography, magnetic resonance imaging,[66] or autopsy findings.[63,65] Two studies[64,67] compared interobserver consistency, 1[66] compared accuracy of 5 sonographers with autopsy findings, and 1 recent study[68] compared accuracy of interpreters' findings with gold standard pictures. All of these found inconsistencies, particularly in the diagnosis of PVL, as well as germinal matrix and choroid plexus lesions. Final diagnosis[67] may be improved using serial studies and also by educational conferences.[64]

Reasons for variability include variation in equipment, including transducer head, quality of the studies, experience of the readers, misinterpretation of periventricular echogenicity, and gestational age of the infant related to changing brain water composition. Thus, the evidence for these PBPs is based on these observational trials as well as on observation and opinion. Currently, the members of the group are jointly implementing practices 2 and 3 with plans to reevaluate performance in the near future.

DISCUSSION

Five NICUs joined to form a group that focused on a common goal: to reduce the incidence of ICH and cystic PVL in VLBW infants. In addition, the need was identified for assessing and improving the consistency of cranial sonogram interpretation.

When developing the practice analysis questionnaire, the group recognized that to see the relation between practices and outcomes, information on practices needed to be chronologically matched with outcome data. This was somewhat problematic because outcome data were from 1997 and 1998 and the questions on practices were answered in 1999. The group also noted that as the individual NICUs summarized their practices for comparison with each other, the variability of practices within each unit became less clearly identifiable. This was possibly a lost opportunity because no significant practice variability was identified within each of the 5 NICUs. Practices did differ between the institutions, but this did not lead to any immediate practice changes.

At the benchmark site visits, the goal was to get as many perceptions of the experience as possible. In addition, visiting emphasized certain aspects of care. For example, 1 of the sites had told us that they emphasized developmental care, but only by visiting them could the extraordinary quiet maintained and the ways in which that quiet affected the infants' clinical stability be appreciated. Visiting also allowed review of aspects of clinical care and administrative support not directly related to the area of focus.

The "video visit" to New Zealand was unique and exciting. All 5 group members had representatives participating in the conference call, and the interactions were believed to be a success. At the same time, the group concluded that having video footage of the NICU and more peer group discussions would enhance future interactions.

Frustrations during the process included 1) lack of strong evidence for some PBPs, 2) getting staff from the home hospitals involved in process improvement using plan-do-study-act quality improvement cycles rather than the old "just do it" method, 3) finding the time to do all of the group work in addition to regular workloads, and 4) trying to implement many changes at one time. Some members of the group were frustrated by the inability to conclude, "ah-ha, so that's it." It has taken time to identify and implement the PBPs, a number of which have relatively "weak" evidence. It is possible that all PBPs to reduce the incidence of ICH and cystic PVL have not been included here. For instance, 1 of the benchmark sites routinely evaluated coagulation and treated abnormal findings with fresh-frozen plasma and cryoprecipitate. Although they also used many of the other PBPs, they believed that this particular practice contributed to their low ICH rate. Nevertheless, evidence could not be found to support this practice. Because of the possible risks and given the paucity of literature on normal coagulation values in this population and on therapy, this practice was not listed as a PBP. However, this an area for additional research.

At its first meeting, the group named itself the Brainy Bunch. To help develop further esprit d'corps, the group collaborated on several creative ideas, including a group song and pictures using its name. Also, the group leader played a big part in the group's success: dedicated to the cause and a very hard worker, he managed to keep the team on track and somewhat organized while still having fun. The group shared data and communicated through e-mails and conference calls. These conference calls ran smoother with an agenda; people showed a tendency to ramble on when the call was unstructured. Physicians tended to dominate the conference calls, and occasionally others had to be encouraged to speak up.

In retrospect, the team should have included maternal-fetal medicine specialists and radiologists from the start of the project, as well as an expert in the interest area. Doing so might have improved the quality of the practice analysis questionnaire, which was too long even after multiple revisions. Also, these practitioners would have better understood the process and felt a greater sense of ownership in the project. An attempt was made to get the maternal-fetal medicine specialists more actively involved in the project during the second year. After some initial enthusiasm, interest declined.

Quality improvement nurses and research analysts have made important contributions, providing expertise in collating information and using database and spreadsheet programs. Three people did this

work over the course of the project. A fourth person developed the database being used in the sonogram project described below.

The sonography study provided some of the most disturbing information and spurred the development of a separate initiative, involving neonatologists and radiologists from each NICU. As a first step in this collaborative effort, a more detailed practice analysis of test methods and sonography interpretation was performed. From this analysis, 5 PBPs were identified related to doing and interpreting cranial sonograms, which were added to the list of clinical practices.

Initially, the radiologists had only mild interest in the sonogram project, and several had to be cajoled to participate in the readings. Once they were able to see the marked inconsistency in interpretation, they became more enthusiastic, but the time commitment required has remained a major problem. Using conference calls, e-mail, and discussions at each participating institution, all parties have agreed on standards for testing methods and rules for interpretation. A set of sonographic pictures to help further standardize both is being created. A database has also been created for each NICU to enter interpretive data. Once these changes are firmly in place, the sonogram study will be repeated to assess improvement. The hope is to be able to show more consistent and reliable interpretation and correlation with long-term improvement in neurodevelopmental outcome.

CONCLUSIONS

Working collaboratively with benchmark NICUs, the team analyzed clinical practices. On the basis of that analysis and the evaluation of the literature, a number of PBPs were identified. Hopefully, implementation of the PBPs will decrease the incidence of ICH and cystic PVL and improve the reliability of sonogram interpretation. Each of the 5 NICUs has been implementing these practices. The 2001 Vermont Oxford Network data will be used to assess the group's success.

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