SUPPLEMENT ARTICLE

Reduction of Bronchopulmonary Dysplasia After Participation in the Breathsavers Group of the Vermont Oxford Network Neonatal Intensive Care Quality Improvement Collaborative

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ABSTRACT

OBJECTIVE. The objective of this study was to compare the primary and secondary outcomes of very low birth weight infants before and after participation in the Breathsavers Group of the Vermont Oxford Network–sponsored Neonatal Intensive Care Quality Collaborative.

METHODS. Hospitals that participated in the Breathsavers Group contributed clinical data on the outcomes of their very low birth weight infants to the Vermont Oxford Network using standardized clinical definitions, data forms, and inclusion criteria. Outcomes from the last year of the collaborative, 2003, were compared with those from the baseline year, 2001. Models for treatment practices and outcomes measures were adjusted for within-hospital correlation (clustering) and standard risk factors that were present at birth.

RESULTS. Bronchopulmonary dysplasia dropped significantly in 2003 compared with the baseline year. Survival improved but not significantly. In addition, severe retinopathy of prematurity, severe intraventricular hemorrhage, and supplemental oxygen at discharge dropped significantly. The use of conventional ventilation at any time during the initial hospitalization, postnatal steroids, and time to first dose of surfactant all decreased significantly. The use of nasal continuous positive airway pressure at any time during hospitalization increased. The use of high-frequency ventilation, delivery room intubation, and surfactant at any time during hospitalization did not change.

CONCLUSIONS. The Breathsavers Group improved both clinical care processes and clinical outcomes during the Neonatal Intensive Care Quality Collaborative.

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Key Words
bronchopulmonary dysplasia, very low birth weight infant, process improvement, NICU, quality improvement

Abbreviations
VON—Vermont Oxford Network
NIC/Q 2002—Neonatal Intensive Care Quality Improvement Collaborative 2002
VLBW—very low birth weight
PBP—potentially better practice
BPD— bronchopulmonary dysplasia
PMA—postmenstrual age
aOR—adjusted odds ratio
CI— confidence interval
ROP—retinopathy of prematurity
SROP—severe retinopathy of prematurity
SIVH—severe intraventricular hemorrhage

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THE VERMONT OXFORD Network (VON) sponsored the Neonatal Intensive Care Quality Improvement Collaborative 2002 (NIC/Q 2002) to help participating NICUs improve the care of very low birth weight (VLBW) infants. Patterned after 2 previous collaboratives,[1–3] the essential components of the NIC/Q 2002 were (1) evidence-based, potentially better practices (PBPs), (2) current methods of quality improvement and adult education, and (3) multiinstitutional collaboration.

Rates of bronchopulmonary dysplasia (BPD) vary widely.[4,5] A previous report from the original NIC/Q collaborative showed a significant decrease in BPD among participants who focused on reducing BPD.[2] However, that report included only 8 institutions. This report examines the changes in clinical outcomes associated with participation in the Breathsavers Group of the NIC/Q 2002. The goal was to reduce BPD by 10% from 2001 to 2003.

METHODS

Participating Centers

The Breathsavers Group consisted of 16 centers and 19 hospitals (see "Acknowledgments" for listing) with Jay P. Goldsmith, MD, medical expert; Meena LaCorte, MD, group leader; and Debra Miller and Diane Miller, facilitators. One center, Columbus Children's Hospital (Columbus, Ohio), was closely associated with 3 referral hospitals (Doctor's Hospital West, Riverside Methodist Hospital, and Grant Medical Center). These 4 hospitals worked very closely with each other and participated in the NIC/Q 2002 as a single center.

The details of participation in the NIC/Q 2002 Breathsavers Group and implementation of the potentially better practices (PBP) are reported elsewhere in this supplement. Outcomes from the first year of the collaborative, 2001, were taken as the baseline year. Almost all PBPs had been implemented by the end of 2002. Therefore, 2003 was chosen as the outcomes measurement year.

Patient Data

Deidentified outcomes data that had been submitted by each participating institution to the VON were collated and analyzed. The clinical definitions of demographic, treatment, and outcome measures were those published annually by the VON.[6–8] The definition of BPD was adjusted to account for infants who were discharged from the hospital before 36 weeks' postmenstrual age (PMA) as follows: VLBW infants with BPD were defined as those who required supplemental oxygen at 36 weeks' PMA. In addition, we classified infants who went home requiring supplemental oxygen at 34 to 36 weeks' PMA as requiring supplemental oxygen at 36 weeks and having BPD. We categorized infants who went home without supplemental oxygen at ≤36 weeks' PMA or who remained hospitalized but did not require supplemental oxygen at 36 weeks' PMA as not having BPD. For all other infants, BPD status was considered unknown. Participating hospitals' Institutional Review Boards approved this use of the data.

Statistical Analysis

Data for VLBW infants (birth weight: 501–1500 g) who were born in 2003 were compared with data from those who were born in 2001. Dichotomous measures of treatment practice and dichotomous outcomes were analyzed using logistic regression. Generalized estimating equations accounted for within-hospital correlation (clustering). Unadjusted analyses included an indicator variable for year of birth (0 = 2001, 1 = 2003) and a measure to indicate whether the hospital also was included in an ongoing delivery room management trial. Adjusted analyses included these 2 predictors, as well as the following covariates: gestational age, small for gestational age (yes or no), maternal race, major birth defect (yes or no), multiple birth (yes or no), Apgar score at 1 minute, gender, mode of delivery (cesarean section or vaginal), and birth location (inborn or outborn).

To determine whether there was a change between 2001 and 2003 for birth weight and gestational age, we used unadjusted random coefficient mixed models, which controlled for clustering within hospitals. For age at first dose of surfactant in infants who received surfactant and length of hospital stay in survivors, we used proportional hazards models, which adjusted for clustering. A maximum age at first surfactant dose was fixed at 1 week, and the maximum length of hospital stay was fixed at 1 year. The unadjusted and adjusted models were based on the log rank test and included the same predictors as used for the logistic models described above. $P < .05$ was considered significant. SAS 8.2 (SAS Institute, Inc, Cary, NC) and Stata 7.0 (Stata Corp, College Station, TX) were used.

RESULTS

Patient Demographic Characteristics

Data were available for all 1757 VLBW infants who were treated in Breathsavers Group institutions in 2001 and for all 1829 infants in 2003. Participating institutions had 12 to 225 VLBW admissions in 2001 and 15 to 242 in 2003, with BPD rates varying from 13.4% to 66.7% in 2001 and 4.0% to 58.3% in 2003 (Fig 1). Demographic data are presented in Table 1. The only significant demographic change was a decrease in white mothers in 2003 compared with 2001 ($P < .001$). Maternal race was included in the adjusted models.

Changes in Treatment Practices

The Breathsavers Group made significant changes in their treatment practices as a result of implementing the

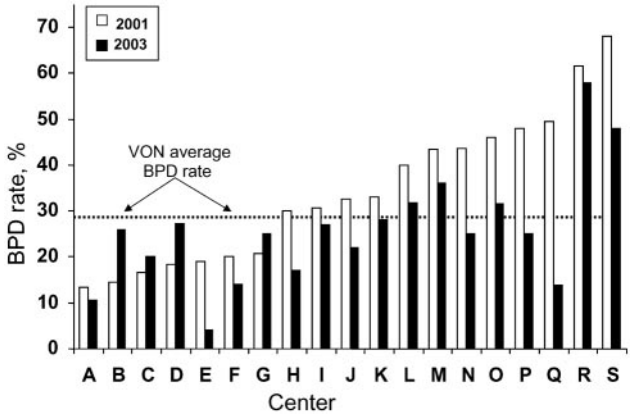

FIGURE 1
Participating hospitals are represented along the x-axis, and BPD rates are noted along the y-axis. Rates for the baseline (2001) and follow-up (2003) years are presented. The average BPD rate for the entire VON VLBW database was the same for 2001 and 2003: 29%. That average rate is represented by the dotted line.

TABLE 1 **Infant Demographic Characteristics at Breathsavers Group Hospitals, 2001 and 2003**

Characteristic	2001 Value	2003 Value	*P*
Location of birth, inborn %	83.3	81.6	.116
Gender, % male	52.0	50.4	.326
Maternal race, % white	65.3	60.6	<.001
Prenatal care, %	95.6	96.8	.070
Any antenatal steroids, %	69.1	69.9	.728
Delivery by cesarean section, %	66.4	69.2	.107
Multiple birth, %	29.6	29.2	.816
Small for gestational age, %	19.6	19.9	.770
Birth weight, mean, g	1061.5	1067.4	.543
Gestational age, mean, wk	28.2	28.3	.446

PBPs. For example, the use of conventional ventilation, postnatal steroids, and supplemental oxygen in the delivery room all decreased significantly (Table 2). The use of nasal continuous positive airway pressure at any time during hospitalization increased significantly from 60.8% to 71.3% (adjusted odds ratio [aOR]: 1.91; 95% confidence interval [CI]: 1.49–2.47), as did the use of surfactant in the delivery room (aOR: 2.27; 95% CI: 1.09–4.72). Participating centers also decreased the median time to first surfactant dose from 22 to 10 minutes after delivery (adjusted hazard ratio: 1.33; 95% CI: 1.03–1.72) and decreased the use of conventional ventilation (aOR: 0.69; 95% CI: 0.55–0.87). There was no change in the use of high-frequency ventilation; surfactant at any time; or delivery room intubation, bag/mask ventilation, or chest compressions (Table 2).

Changes in BPD Rates

BPD, whether using the classic definition of requirement for supplemental oxygen at 36 weeks' PMA or adjusted BPD (see "Methods"), was less common in 2003 than in 2001 at the Breathsavers Group hospitals (Table 3). For example, the aOR for adjusted BPD was 0.51 (95% CI: 0.37–0.72). Survival without BPD rose from 53.6% to 63.4% (aOR: 1.86; 95% CI: 1.41–2.46; Table 3). However, the reduction in BPD was not uniform across all participating centers. Fourteen institutions decreased their BPD rate from 2001 to 2003, but 4 centers had an increase (Fig 1). Some institutions had unusually low BPD rates, probably because many of their sickest infants were transferred to a referral center (see "Methods"). Overall, Breathsavers Group centers reduced BPD in 2003 compared with 2001 by 27%, exceeding the goal of a 10% reduction. By comparison, BPD rates for all centers in the VON was 29% in both 2001 and 2003.

Changes in Secondary Outcome Measures

In addition to reducing BPD, Breathsavers Group centers significantly reduced the use of supplemental oxygen at discharge, severe retinopathy of prematurity (SROP), and severe intraventricular hemorrhage (SIVH) (Table 3). Survival among Breathsavers Group centers' patients was slightly but not statistically higher for 2003 compared with 2001 (86.1% vs 84.3%). Other complications, such as pneumothorax, nosocomial bacterial infection, any late infection, periventricular leukomalacia, and necrotizing enterocolitis, did not change signifi-

TABLE 2 **Treatment Practices at Breathsavers Group Hospitals, 2001 and 2003**

Treatment Practice, %	2001 Value	2003 Value	Unadjusted OR (95% CI)	aOR (95% CI)
Delivery room care				
Supplemental oxygen	94.2	90.1	0.56 (0.35–0.88)	0.52 (0.30–0.91)
Bag/mask	48.3	52.7	1.19 (0.85–1.67)	1.18 (0.78–1.79)
ETT/ventilation	59.5	59.5	1.00 (0.73–1.36)	1.06 (0.69–1.63)
Chest compressions	6.8	7.7	1.14 (0.90–1.44)	1.05 (0.76–1.45)
Surfactant	32.2	45.2	1.74 (0.93–3.23)	2.27 (1.09–4.72)
Surfactant at any time	70.1	69.2	0.96 (0.73–1.26)	1.02 (0.77–1.35)
Conventional ventilation	72.3	66.1	0.75 (0.61–0.91)	0.69 (0.55–0.87)
NCPAP	60.8	71.3	1.60 (1.31–1.96)	1.91 (1.49–2.47)
High-frequency ventilation	28.9	27.9	0.95 (0.70–1.29)	0.94 (0.66–1.33)
Steroids for BPD	16.9	6.7	0.35 (0.26–0.49)	0.30 (0.21–0.44)

ETT indicates endotracheal tube; NCPAP, nasal continuous positive airway pressure.

TABLE 3 **Outcomes at Breathsavers Group Hospitals, 2001 and 2003**

Outcome, %	2001 Value	2003 Value	Unadjusted OR (95% CI)	aOR (95% CI)
Survival	84.3	86.1	1.15 (0.95–1.40)	1.27 (0.95–1.71)
BPD at 36 wk PMA	36.6	26.8	0.63 (0.49–0.82)	0.51 (0.37–0.72)
Oxygen at 36 wk PMA	45.8	35.1	0.64 (0.50–0.82)	0.52 (0.38–0.72)
Survival without BPD	53.6	63.4	1.50 (1.22–1.84)	1.86 (1.41–2.46)
Oxygen at discharge	25.9	17.2	0.59 (0.43–0.83)	0.53 (0.38–0.75)
Pneumothorax	6.7	5.9	0.87 (0.68–1.13)	0.86 (0.63–1.17)
SROP	12.3	9.1	0.72 (0.46–1.11)	0.59 (0.37–0.94)
SIVH	11.3	9.6	0.84 (0.72–0.98)	0.79 (0.67–0.92)
Periventricular leukomalacia	3.6	3.0	0.81 (0.51–1.29)	0.82 (0.50–1.35)
Bacterial nosocomial infection	20.8	20.0	0.95 (0.71–1.29)	0.93 (0.69–1.25)
Any late infection (includes fungal infections)	22.3	20.8	0.92 (0.70–1.20)	0.89 (0.68–1.16)
Necrotizing enterocolitis	6.3	7.0	1.11 (0.87–1.44)	1.12 (0.85–1.47)

cantly. Median length of stay in surviving infants also did not change (55 vs 54 days; adjusted hazard ratio: 1.13; 95%, CI: 0.99–1.30).

DISCUSSION

This study supports the hypothesis that quality improvement collaboratives can improve NICU outcomes for VLBW infants. The outcomes that were associated with the Breathsavers Group's efforts were better than expected. The primary goal was a 10% reduction in BPD with no change in mortality. A 27% reduction was achieved. These improvements compare favorably with other reports of collaborative quality improvement.[2,9–12]

Not all participating centers demonstrated reduced BPD rates after implementing the PBPs. The 4 centers that did not show improvements had baseline BPD rates <29%, the average for all VON centers in 2001 (Fig 1). The NICUs that showed the greatest improvement generally had baseline BPD rates that were higher than the overall VON average. This suggests that the NICUs that are most likely to benefit from improvement efforts might be those that have higher than average baseline rates.

One of the PBPs implemented by the Breathsavers Group was a reduction in oxygen saturation targets for VLBW infants. This was shown previously to reduce BPD and ROP.[12–14] Changing the oxygen saturation target might reduce the number of infants who meet the criterion for BPD without changing the infant's condition. This would result in fewer infants being classified as having BPD, although their physiologic condition would be comparable to those who previously received a diagnosis of having BPD using higher oxygen saturation targets. Walsh et al[15] showed that changes in the diagnostic criteria of BPD can alter the reported incidence of BPD. We cannot exclude that possibility. Although lower oxygen saturation targets might have reduced artificially the rate of BPD, they are not likely to have changed the rates of SROP or SIVH, both of which were reduced in 2003 compared with the baseline year, 2001 (Table 3). Furthermore, reducing the administration of unnecessary supplemental oxygen has merit, even if it does not reduce BPD.

The Breathsavers Group could have shown improved outcomes for reasons other than just the implementation of PBPs. For example, the Hawthorne effect, improvement in performance that is seen when performance receives extra scrutiny, might have accounted for some of the improvement that was seen in this collaborative. Such improvements would be expected to last only as long as the increased scrutiny lasted and would be independent of any relationship (or lack of relationship) between the changes in care (PBPs) and clinical outcomes. If the Hawthorne effect were the only explanation for our observed improvement in outcomes, then the value of the collaborative would be changed from the implementation of evidence-based PBP to increasing awareness of BPD among the participating centers. Some investigators have even discussed the value of harnessing the Hawthorne effect to improve care.[16,17] The key observation is that outcomes were improved, whatever the mechanism.

Although there may have been some influence from the Hawthorne effect, the Breathsavers Group likely improved outcomes through the implementation of PBPs that improved the team work, culture, and level of collaboration among professional disciplines. The Breathsavers Group improved treatment processes such as reducing the time to first surfactant and the use of conventional ventilation. Similarly, the Breathsavers Group increased surfactant use in the delivery room and the use of nasal continuous positive airway pressure (Table 2). These changes in clinical care likely led to a reduction in BPD. There also may have been a reduction in severity of BPD that did not appear in our data, because this study did not stratify cases of BPD using the National Institute of Child Health and Human Development consensus criteria.[18] Furthermore, the Breathsavers Group improved related outcomes, such as SROP and SIVH, that were not the intended objectives of the col-

laborative and likely would not have been affected by increased scrutiny of respiratory practices and outcomes.

This study showed that in the year after implementation of the PBPs, the Breathsavers Group produced significant improvements in treatment and outcome measures. However, these improvements may not be sustained as the effort to implement new PBPs wanes and NICU personnel return to former practices. Follow-up studies to monitor changes in the BPD rate in participating institutions will be needed to augment this initial report.

CONCLUSIONS

The Breathsavers Group made significant improvements in clinical care and reduced BPD as a part of the NIC/Q 2002 quality collaborative. There is a need to monitor the Breathsavers Group NICUs' respiratory outcomes in future years to evaluate the durability of the improvements reported here. However, the Breathsavers Group's experience supports the value of quality collaboratives as a method of improving NICU care.

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