Individualized Developmental Care for Very-Low-Birth-Weight Premature Infants

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Summary: Forty very-low-birth-weight neonatal intensive care unit (NICU) infants with birth weights ≤1,250 g were randomly assigned to treatment or control groups. Behavior of the treatment infants was systematically evaluated, and individualized developmentally oriented care plans were implemented to enhance stability. Treatment babies required fewer days of intermittent mandatory ventilation and continuous positive airway pressure and achieved full enteral feedings sooner. Length of hospital stay and hospital charges were less for treatment than control infants. There were favorable effects on treatment infants' behavioral performance at 42 weeks' postconceptional age. These results support the hypothesis that behaviorally sensitive, developmentally oriented care improves medical and neurodevelopmental outcome in the NICU.

Introduction

Very-low-birth-weight (VLBW) infants make up a small percentage of births and neonatal intensive care unit (NICU) admissions in most centers (approximately 15% at our facility).[1,2] However, they add disproportionately to mortality, morbidity, and the cost of medical care.[3-6] The incidence of bronchopulmonary dysplasia (BPD) may be as high as 42% in this population.[7] Long-term neurodevelopmental difficulties also plague survivors in this group.[8] A review of trends in the incidence of cerebral palsy noted increased prevalence due to improved survival of VLBW infants.[9] Differences in developmental and intelligence quotients have been reported to differentiate low-birth-weight infants from controls.[8,10] Increased frequency of behavior and school problems has also been noted.[10]

Nontechnological behavioral interventions have produced favorable effects on short-term medical and neurodevelopmental outcomes, as well as at long-term follow-up.[11-15] In two separate studies, Als et al[11,14] found that behavioral intervention significantly reduced days on the ventilator, oxygen, and on gavage feeds. Becker et al[12] found that infants who received individualized behaviorally based care demonstrated more optimal respiratory and feeding status, lower levels of morbidity,

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This investigation was supported by the Division of Neonatal and Developmental Medicine, Department of Pediatrics, Stanford University School of Medicine; by a grant (M01-RR00070) from the National Institutes of Health; by the Children's Health Council; by a grant from the David and Lucile Packard Foundation; and by the Mary L. Johnson Research Fund.

Table 1

MATERNAL AND NEONATAL CHARACTERISTICS

	Treatment n = 17	Control n = 18
Mother		
Age (yr)		
Mean	25.8	30.2
Range	(17-39)	(15-44)
Years of schooling		
Mean	13.2	13.8
Range	(6-20)	(9-18)
SES*		
Mean	38.0	38.6
Range	(8-66)	(6-60)
Infant		
Birth weight (g)		
Mean	892.7	815.0
Range	(540-1,180)	(525-1,237)
Gestational age (wk)		
Mean	26.5	26.1
Range	(24.0-29.4)	(23.9-28.7)

*Socioeconomic status as measured by Hollingshead Four Factor Index.[22]
None of the between-group differences attains statistical significance at $P = 0.05$.

shorter hospital stays, and improved behavioral organization.

We sought to demonstrate that these bedside caregiving strategies would produce similar positive results at our institution with de novo introduction of behaviorally oriented care. This study is also noteworthy for the randomized assignment of high-risk inborn and outborn VLBW prematures in the surfactant era. We hypothesized that the treatment group would show benefit in each of the following medical outcome variables: (1) shorter time on intermittent mandatory ventilation (IMV) and continuous positive airway pressure (CPAP); (2) shorter time to full enteral feedings; (3) earlier postconceptional age (PCA) at discharge; (4) reduced degree of chronicity; (5) shorter time to hospital discharge; and (6) reduced hospital charges. We also hypothesized that treatment infants would show better neurobehavioral outcome at 42 weeks' PCA, as measured by the Assessment of Preterm Infants' Behavior (APIB).[16,17]

Methods

This study was conducted in the neonatal and intermediate intensive care nurseries at Lucile Salter Packard Children's Hospital at Stanford, where primary-care nursing is practiced. Seventy-six of the 185-member nursing staff received introductory training in behavioral assessment and care prior to and during the course of this study.

Patient Sample

During the recruitment phase from July 1992 to March 1994, 40 infants with birth weight ≤1,250 g and gestational age ≤30 weeks were enrolled in this study. One hundred forty other infants with similar birth weights and gestational ages were excluded for the following reasons: (1) multiple gestation; (2) mechanical ventilation not begun in the first 3 hours or continued for more than 24 of the first 48 hours of life; (3) chromosomal abnormalities, congenital anomalies, or infection; (4) parents lived beyond a predesignated catchment area; (5) parents were non-English speaking; and (6) enrollment in other research studies with conflicting goals. These criteria allowed us to select infants with high likelihood of medical morbidity and, at the same time, with potential for normal long-term medical and neurodevelopmental outcome. Unavailability of staff precluded six infants from being recruited. Five of the 40 enrollees died between 2 and 50 days after birth. Patients were enrolled only after appropriate eligibility criteria were met and after we obtained informed consent from one or both parents. Infants were then randomly assigned to treatment or control groups by use of sealed envelopes. The study was approved by the Panel on Human Subjects in Medical Research at Stanford University.

Treatment Program

Patients randomly assigned to the control group (n = 18 survivors) received routine care as practiced in our nurseries during this study. This included primary nursing; some shielding of incubators; attention to positioning, handling, and feeding practices; and referral to occupational or physical therapy after stabilization when deemed appropriate by the caregiving staff. Control infants were not specifically identified, and assignment of caregivers for control infants was not influenced. Some of the nurses assigned to control patients had taken educational classes offered by the developmental specialists. Many were familiar with the caregiving techniques provided systematically to the treatment infants. Patients randomly assigned to the treatment group (n = 17 survivors) were evaluated by the certified developmental specialists with interevaluator reliability of greater than 85%. Evaluations were performed within 24 hours of admission and weekly thereafter. At each evaluation, the *Manual for the Naturalistic Observation of the Newborn*[18] provided data about the infant's autonomic reactivity (respirations, heart rate, color changes, visceral signs), motor system function (posture, muscle tone, and movements), state of sleep or wakefulness, self-regulatory ability, and, as infants became more stable, interactive availability. Observations were conducted for 20 minutes before and after routine caregiving and during the handling. Infants' responses were recorded every 2 minutes.

Based on these assessments, individualized care plans were developed by the developmental specialists in conjunction with the primary nurses and the parents for each treatment baby. Seventy-six of the 185-member nursing staff had received introductory training in newborn infant behavior and development prior to and during the course of the study. Fifteen of these nurses completed more intensive behaviorally oriented training and volunteered to become the primary nurses for the treatment babies. These nurses cared for treatment infants two shifts out of three and were available up to 5 of every 7 days. The developmental specialists made bedside visits several times each shift to ensure consistency. The focus of the visits was to provide guided care to the infants and support to the caregivers.

Specific caregiving techniques, described elsewhere,[19-21] included (1) alteration of the environment by modulation of lighting and noise; adaptation of covers to the incubators and cribs; (2) use of positioning aids, such as boundary supports, nests, and buntings, to promote a balance of flexion and extension postures; infants were placed prone or side-lying; (3) modification of direct hands-on caregiving to maximize preparation of infants for and facilitation of recovery from interventions; (4) promotion of self-regulatory behaviors such as holding on, grasping, and sucking; (5) attention to the readiness for and ability to take oral feedings; (6) involvement of parents in the care of their infants as much as possible.

Support for parents was provided on a daily basis. They were encouraged to nurture and support their infants during procedures and to hold their infants as soon as possible. Breast-feeding was encouraged. The developmental specialists and primary nurses facilitated family involvement by keeping in contact with parents by phone when they could not visit.

Table 2

MEDICAL TREATMENTS AND COMPLICATIONS

	Treatment n = 17	Control n = 18
Antenatal steroids — yes/no	6/11	5/1
Surfactant doses	50	62
Positive pressure/O_2 at 28 wks' PCA	13	15
O_2 at 28 days	17	18
Positive pressure/O_2 at 36 wks' PCA	1	4
O_2 at 36 wks' PCA	14	1
IVH Grade I-II/III-IV	6/3	4/4
PIE	3	6
PDA (indomethacin/surgery)	10/5	9/7
NEC (pneumatosis or perforation/suspected)	0/3	2/8
ROP Stage I-II/III	8/6	10/5
Sepsis and fungemia/meningitis	8/1	8/1

PCA = postconceptional age; IVH = intraventricular hemorrhage; PIE = pulmonary interstitial emphysema; PDA = patent ductus arteriosus; NEC = necrotizing enterocolitis; ROP = retinopathy of prematurity.
None of the between-group differences attains statistical significance at $P = 0.05$.

Table 3

RESPIRATORY SCORES AND NEONATAL MEDICAL INDEX

	Treatment n = 17	Control n = 18
PIP 12 hours		
Mean	19.6	19.7
Range	(14-24)	(13-27)
NMI at discharge		
Mean	4.5	4.6
Range	(3-5)	(3-5)

PIP = peak inspiratory pressure; NMI = Neonatal Medical Index.
None of the between-group differences attains statistical significance at $P = 0.05$.

Data Collection and Analysis

Maternal and neonatal characteristics of surviving infants, which included mother's age, level of education, and socioeconomic status (SES),[22] and infant's birth weight and gestational age, are shown in Table 1. Racial distribution was similar in the two groups and no significant differences were found in gender, Apgar scores,[23] and inborn vs outborn status. Gestational age was estimated prior to randomization by use of obstetric dates. Any discrepancies between obstetric dates and the modified Ballard examination[24] were reconciled by an investigator (BEF) after review of the maternal history, data gathered during pregnancy (e.g., sonograms), and after reexamination. Comparisons of treatment and control groups for medical treatments and complications are shown in Table 2. Surfactant doses are compared by *t*-test; all other comparisons in Table 2 are made by Fisher's Exact Test. The groups were compared early in life for risk of later supplemental oxygen requirement using the scoring system developed by Sinkin et al,[25] who employed the peak inspiratory pressure (PIP) at 12 hours of age (Table 3). We also assessed treatment and control groups for comparability of medical complications during the hospital stay using the Neonatal Medical Index (NMI), a tool that "summarizes, in bold strokes, infants' medical course during their stay in hospital"[26] (Table 3).

Medical Outcome

Medical outcome variables (Table 4) included time on IMV and/or CPAP and days to full enteral feeding. Chronicity was assessed by comparing numbers of infants in each group discharged after 42 weeks' PCA. Postconceptional age at discharge, duration of hospital stay, and total hospital charges were evaluated. These variables were selected because they represent markers of stability and final common pathways to and/or important milestones in recovery.

Neurodevelopmental Outcome

The APIB[16,17] examination was completed at 42 weeks' PCA by an APIB-certified examiner masked to the group assignment of the infant. The APIB assesses an infant's behavior in five areas or systems, including the autonomic system, the motor system, the state system, the attentional system, and the self-regulatory system. The degree of examiner facilitation needed during the evaluation is also scored. Motor system organization is manifest by an infant's posture, muscle tone, and patterns of movement. State system control is defined by evaluation of the sleep and wake states, as well as by the transition between sleep and waking. Attentiveness and interactive abilities are assessed by evaluating the infant's ability to respond to stimuli. Self-regulatory skills are manifest by an infant's ability to use various physiologic, postural, and/or behavioral strategies to maintain itself in more stable states. System scores range from 9 for the least organized to 1 for the most organized performance.

Results

The treatment and control groups were statistically similar with respect to maternal and neonatal characteristics (Table 1), both with and without the nonsurvivors. Table 2 shows the medical treatments and complications for the 35 survivors. Early prediction of oxygen requirement at 28 days (and arguably the risk for chronic lung disease) was assessed by the scoring system developed by Sinkin et al employing the PIP at 12 hours of age.[25] The need for pressure support was statistically similar in the two groups, suggesting similar severity of respiratory illness at this relatively early time. The NMI allows comparisons of medical complexity assessed at the end of the hospital stay and is heavily weighted by time on the ventilator, a final common pathway indicative of morbidity in this population.[26] This tool supported our findings that there were no statistically significant differences in medical complications between the two groups. However, the limited five-point scoring system of the NMI does not allow for sufficiently precise differentiation of babies with a prolonged course of ventilation. Both the Sinkin score and the NMI have been previously tested and offer the advantage of being straightforward in their application (Table 3).

Medical outcome data are shown in Table 4. Examination of the medical outcome data reveals that the treatment group benefitted from the interventions in a consistent and uniform fashion as hypothesized. *P* values of 0.05-0.09 are noted with two-tailed testing.

Developmental outcome data are presented in Table 5. At 42 weeks' PCA, four of the six APIB system scores significantly favored the experimental group ($P \leq 0.05$). Their lower scores indicate more organized performance in motor system function, state regulation, interactive capabilities, and in ability to self-regulate.

Table 4

MEDICAL OUTCOME DATA

	Treatment n = 17	Control n = 18	P*
Days on positive pressure			
Mean	37.6	59.7	0.05
Range	(5-90)	(11-155)	
Days on enteral feeds			
Mean	22.9	36.5	0.09
Range	(8-43)	(9-135)	
Postconceptional age at discharge (wk)			
Mean	39.4	42.2	0.08
Range	(34.4-42.2)	(36.3-53.9)	
Chronicity**			
Mean	1	7	0.05***
Days in hospital			
Mean	91.5	115.2	0.08
Range	(47-158)	(55-210)	
Hospital charges ($)			
Mean	362	491	0.06
Range	(110-646)	(184-986)	

*Two-tailed *t*-test.
**Chronicity is defined by duration of stay past 42 weeks' postconceptional age.
****P* value calculated by Fisher's Exact Test.

Discussion

The study design included potentially confounding variables that must be discussed. The attending neonatologists were not systematically masked to the baby's status in this study because the shielding of incubators, use of positioning aids, and presence of bedside-care plans differentiated experimental from control infants. However, decisions to extubate or discontinue CPAP were made according to reasonably consistent guidelines in our nursery and were made by several different neonatologists during the course of the study. These factors mitigated against bias to discontinue pressure support too early in the treatment group. It is noteworthy that our control patients required fewer days of IMV and/or CPAP than IMV alone in the control group of Als et al.[17] This finding could be explained by the extensive use of surfactant during the years of our study. Overly aggressive efforts to advance enteral feedings might have resulted in a higher incidence of gastrointestinal problems such as feeding intolerance or necrotizing enterocolitis (NEC). In fact, the incidence of suspected NEC (defined as feeding intolerance sufficient to withhold enteral feeds for at least 72 hours) was higher in the control group. Consistency of nursing care alone might have been expected to have a favorable impact on treatment patients. However, control infants also received primary-care nursing. For that reason, we believe that our intervention program provided incremental benefit. Hospital discharge is also planned according to reasonably consistent guidelines. Thus, we do not believe that bias in favor of treatment infants was likely to have affected their duration of hospitalization.

The mechanisms by which these interventions produce favorable effects still need to be elucidated. Our treatment infants seem to have been less agitated, presumably a

Table 5

NEURODEVELOPMENTAL OUTCOME APIB SYSTEM SCORES

	Treatment n = 17	Control n = 18	P*
Physiologic			
Mean	6.21	6.88	0.09
Range	(4.33-7.58)	(5.28-9.0)	
Motor			
Mean	5.72	6.58	0.02
Range	(4.44-6.84)	(5.11-9.0)	
State			
Mean	5.75	6.59	0.03
Range	(4.55-8.1)	(5.40-9.0)	
Attention			
Mean	6.90	7.64	0.05
Range	(3.0-8.0)	(5.90-9.0)	
Regulatory			
Mean	5.95	6.88	0.02
Range	(3.94-7.41)	(5.33-9.0)	
Examiner facilitation			
Mean	7.63	8.24	0.07
Range	(5.0-9.0)	(7.17-9.0)	

APIB = Assessment of Preterm Infant's Behavior
*Two-tailed *t*-test was used to compare group differences.

result of this caregiving program. Reduced agitation may explain the reduced need for pressure support, the improved tolerance of enteral feeds, and has been suggested to enhance brain development.[27,28]

The substantial reduction in hospital charges for treatment infants presumably bears a direct relationship to hospital costs, which are more difficult to ascertain. Charges provide a more uniform measure than reimbursements. While there is a wide range of charges for both groups, it should be noted that there were six control infants whose charges exceeded $600,000 each. Only one treatment baby accrued such high charges. Our data do not include physician fees or the charges for providing developmental assessments. Nursing-care hours may have been increased early in the course of each treatment infant's illness due to the nature of the intervention program. However, treatment infants convalesced more rapidly, achieved a lower level of acuity, and thereby obtained a more favorable nurse-to-patient ratio and consequent reduction in total nursing costs.

At an average reduction of charges of $128,670 per treatment patient, charges for the 17 survivors were $2,187,390 less than for an equal number of controls. This saving was approximately 10 times the cost of the developmental service component of the program. With increased training, experience, and sensitivity of all bedside caregivers, these expenses should decrease even further and could be spread over a larger number of nursery patients.

Conclusion

This randomized control study of individualized behaviorally oriented care in the surfactant era for VLBW prematures admitted to a tertiary level NICU with primary-care nursing demonstrates a favorable effect on medical and early neurodevelopmental outcome. It also confirms similar findings at other institutions. In addition to reduced morbidity, the program is strikingly cost-effective. We are now evaluating long-term neurodevelopmental outcome. Additional studies are needed to elucidate the mechanism of action of these interventions and to determine their applicability to other populations, including more mature, small-for-gestational-age, and drug-exposed infants.

Acknowledgment

We are indebted to Lincoln Moses, Ph.D, Department of Health Policy and Research, Stanford University School of Medicine, for biostatistical consultation.

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