Original Article

Efficiency of Breastfeeding as Compared to Bottle-Feeding in Very Low Birth Weight (VLBW, <1.5 kg) Infants

Lydia Furman, MD
Nori Minich, BS

OBJECTIVES:

To examine feeding efficiency and correlates of feeding behaviors in breastfeeding as compared with bottle-feeding VLBW infants at 35 weeks corrected age (CA, postmenstrual plus chronologic age).

STUDY DESIGN:

In all, 105 singleton VLBW infants underwent a standardized feeding observation, of whom 35 were observed breastfeeding and 70 bottle-feeding. Intake, efficiency, and feeding behaviors were compared, and effects of infant and maternal factors were examined.

RESULTS:

Breastfeeding as compared with bottle-feeding infants took in smaller volumes (median 6.5 vs 30.5 ml, $p<0.001$), fed less efficiently (median 0.6 vs 2.2 ml/min, $p<0.001$), and spent less time with sucking bursts (mean 33 vs 55%, $p<0.001$). For breastfed infants, birth and neonatal factors and prior maternal breastfeeding experience were not associated with feeding efficiency or behaviors.

CONCLUSION:

Feeding performance of breastfeeding compared with bottle-feeding VLBW infants at 35 weeks CA is worrisome, and lactation intervention is needed for discharge planning.
Journal of Perinatology (2004) **24,** 706–713. doi:10.1038/sj.jp.7211175
Published online 12 August 2004

INTRODUCTION

Breastfeeding is strongly encouraged for very-low-birth-weight (VLBW, <1.5 kg) infants, but few studies have examined the efficiency of breastfeeding in this population, or compared breastfeeding to bottle-feeding. Information is needed to plan for discharge of VLBW infants whose mothers seek to breastfeed.

Initially studies focused on infant responses to breastfeeding as compared with bottle-feeding. Meier and Anderson[1] studied duration of feeding, ''feeding ability'', transcutaneous oxygen pressure, and body temperature at 32 to 39 weeks corrected age (CA) in five VLBW infants, each of whom served as his/her own control for bottle- and breast-feeding. They reported that during breastfeeding, infants had better integration of respiratory function as evidenced by briefer and fewer hypoxic episodes, but took longer to feed.

Martell et al.[2] compared 16 low-birth-weight infants (LBW, birth weight <2.5 kg) who breastfed with 46 LBW infants who bottle-fed at 32 to 36 weeks CA. They too found a longer duration of feeding in the breastfeeding infants. Breast- and bottle-feeding infants had similar intakes in ml/kg/feed, but bottle-feeding infants had a higher feeding efficiency (ml/minute intake). Martell et al. reported ''high variability'' in suction time and flow velocity for breastfeeding infants of lower gestational ages.

Other studies have examined either breastfeeding only or bottle-feeding only in VLBW infants, and most studies seek to elucidate factors predictive of feeding efficiency or feeding success by term.

Nyqvist et al.[3,4] studied 71 breastfeeding VLBW infants of gestational ages 26 to 35 weeks using the Premature Infant Breastfeeding Behavior Scale (PIBBS), and subsequently studied a convenience sample of 26 breastfeeding VLBW infants in order to correlate oral electromyogram and direct observation of sucking. Infants with any condition that could adversely affect oromotor behavior, including oxygen dependence beyond 28 days of life and Grade 3 or 4 intraventricular hemorrhage, were excluded from both studies. In the first study they reported that infant birth data, neonatal morbidity measures and maternal factors provided ''limited explanations of differences in infant behavior at the breast'' for infants 32 to 36 weeks CA.[3] Better feeding efficiency was associated with decreased ventilator dependence and lack of treatment with theophylline. Maternal factors associated with higher PIBBS score included not smoking, previous experience with breastfeeding, and lower educational level. In the second study they found that older postnatal age was associated with a higher mean duration of sucks, but other differences in sucking behavior were not explained by postnatal or postconceptional age.[4]

Others have examined bottle-feeding in VLBW infants. Lau et al.[5] used feeding efficiency (ml/minute), proficiency (percent of the feeding volume transferred in the first 5 minutes) and overall

Department of Pediatrics (L.F., N.M.), Case Western Reserve University, Cleveland, OH, USA.

Address correspondence and reprint requests to L. Furman, MD, Division of General Academic Pediatrics, Mail Stop 6019, Rainbow Babies and Children's Hospital, University Hospitals of Cleveland, 11100 Euclid Avenue, Cleveland, OH 44106, USA.

transfer (percent of total feeding taken in) as measures, and Gewolb et al.[6] examined number and duration of sucking bursts. Both reported that postconceptional, but not postnatal, age is a predictor of bottle-feeding success in healthy VLBW infants. Medhoff-Cooper et al.[7] used the Kron Nutritive Sucking Apparatus and compared bottle-feeding at 40 weeks corrected age (term) between newly born full-term infants, VLBW infants of gestational ages 24 to 29 weeks, and VLBW infants of gestational ages 30 to 32 weeks. In this study, both more mature postnatal and postconceptional age contributed to sucking performance.

Thus, although breastfeeding is strongly encouraged in mothers of VLBW infants, little information is available to guide expectations for feeding performance. Meier and Anderson[1] compared breastfeeding and bottle-feeding in five VLBW infants only. The work of Nyqvist et al.[3,4] examines feeding efficiency of a much larger sample of breastfeeding VLBW infants, but excludes ill infants with neonatal risk factors such as chronic lung disease and severe intracranial ultrasound result. Most VLBW infants are being readied for discharge at 34 to 35 weeks postconceptional age, with the expectation of weight gain with full oral feeds. Thus, studies directly comparing the feeding efficiency and oromotor behaviors of breastfeeding and bottle-feeding in VLBW infants at this age are needed to facilitate realistic discharge planning.

Our research objectives were: (1) to compare breastfeeding to bottle-feeding in VLBW infants at 35 weeks corrected age (CA, postmenstrual plus chronologic age), and (2) to examine correlates of feeding efficiency and behaviors, including maternal factors, infant birth data and neonatal morbidity.

MATERIALS AND METHODS

The population included participants in a study on the effects of breastfeeding on early outcomes of VLBW infants.[8,9] In all, 344 infants were admitted to the neonatal intensive care unit at Rainbow Babies and Children's Hospital, Cleveland, OH from January 1, 1997 to February 14, 1999, of whom 149 were eligible for the study and 119 (80%) consented to participate. Criteria for population selection have been reported previously, and included singleton birth, birth weight between 600 and 1499 g, gestational age less than 33 weeks gestation, absence of positive drug screen, major congenital anomaly or intrauterine infection, and absence of maternal social factors such as a custody dispute. All mothers were strongly encouraged to provide breastmilk for their premature infants per hospital policy. Lactation consultants and neonatal nurses provide ongoing support to breastfeeding mothers. The study was approved by the Institutional Review Board of University Hospitals, and informed consent was obtained from each participant.

Maternal descriptors and birth data for the 119 study infants have been reported.[8,9] The participating infants had a mean birth weight of 1056 g, a mean gestational age of 28 weeks, 68 (57%) were male, 114 (96%) were inborn, and nine (8%) were small for gestational age. Their mothers were a mean of 27 years old, 55 (46%) were married, 51 (43%) were white, and 25 (21%) had less than a high school education. A total of 32 (27%) of the mothers intended to formula feed, and 87 (73%) of the mothers initially intended to breastfeed, of whom 49 (56%) were still lactating at 35 weeks CA.

A total of 105 (88%) of the 119 infants underwent a standardized Feeding Observation at a mean CA of 35±1 weeks. In all, 14 infants were not observed feeding because they were gavage-fed only ($n = 10$), were not receiving feeds by mouth ($n = 2$), had been discharged ($n = 1$), or the observation was not completed ($n = 1$). The infants who did not have a feeding observation, as compared with those who did, had a lower birth weight (922 vs 1074 g, $p<0.05$), a higher neonatal risk score (4.6 vs 2.5, $p<0.001$), a longer duration of ventilator dependence (36 vs 12 days, $p<0.05$), and more had severe cranial ultrasound abnormalities (36% vs 11%, $p<0.05$).

14 (29%) of the 49 mothers still lactating at the time of the observation chose to feed by bottle rather than at the breast for the feeding observation, so 35 infants were observed breastfeeding, and 70 were observed bottle-feeding. There was no difference between the infants who were breastfed as compared with those who were bottle-fed in mean birth weight (1064 vs 1078 g, $p = 0.79$), gestational age (28±2 weeks for both groups, $p = 0.58$), sex (63 vs 51% male, $p = 0.37$), neonatal risk score (2.9 vs 2.4, $p = 0.20$), severe cranial ultrasound abnormality (14 vs 10%, $p = 0.53$), postnatal age (54±18 days vs 51±18 days, $p = 0.43$) or postconceptional age (35±1 weeks for both groups, $p = 0.46$). 12 (34%) of the breastfeeding infants and 21 (30%) of the bottle-feeding infants were receiving oxygen during the observation. The mothers who breastfed for the observation as compared with those who bottle-fed had more years of formal education (14 vs 12 years, $p<0.01$), and more were married (66 vs 40% married, $p<0.05$), but mothers did not differ with respect to age (29 vs 27 years, $p = 0.11$) or race (51 vs 40% Caucasian, $p = 0.27$). A total of 13 (37%) of the mothers who breastfed for the observation had breastfed a previous child.

Infant neurodevelopmental status was assessed at 35 weeks CA with the Korner Neurodevelopmental Assessment of the Preterm Infant (NAPI). The NAPI is a reliable and previously validated method of assessing infant state and developmental status in 32 to 37 weeks CA preterm infants.[10] In all, 33 (94%) of the breastfeeding infants and 65 (93%) of the bottle-feeding infants who underwent the feeding observation had a NAPI performed at a mean of 36 and 35 weeks CA, respectively. No significant differences were found in any of the mean subscale scores on the NAPI between the breastfeeding and bottle-feeding infants.

The Feeding Observation was designed to evaluate breastfeeding and bottle-feeding in preterm infants (Figure 1). It includes an

MILK STUDY - BEHAVIORAL FEEDING ASSESSMENT *

Name_______________ Date:__/__/__ DOB:__/__/__ Study #_______

Postnatal age in days:_____ Timesince last feed:____minutes **Oxygen**? NC/BB/No **NG**? Yes/No **Breast Bottle** (circle one)

Time in minutes		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
INFANT STATE:	Alert/awake																					
	Drowsy																					
	Asleep																					
	Fussy																					
	Crying																					
STIMULATION:	Jiggle																					
	Unwrap/swaddle																					
	Elicit root																					
	Wiggle nipple																					
LATCH ON:	Rooting																					
	Partial mouth opening																					
	Mouth opening																					
	No mouth opening																					
	Lick/nuzzle																					
	Partial seal																					
	Complete seal																					
SUCK:	Mouthing																					
	Single suck																					
	Sucking burst																					
BURPING:																						
RESTING:																						

If bottle, amount taken:___ml If breast, time:___ Side 1:____min Side 2:____min Total minutes:______

Pre-weight grams:______ Post-weight grams:_____ Weight gain_______

*Adapted from Nyqvist KH, Robertson D, Ewald M, et al. Development of the preterm infant breastfeeding scale (PIBBS): a study of nurse-mother agreement. *J Human Lact* 1996;12:207-219.

Figure 1. Feeding observation form.

assessment of infant state of arousal, infant oromotor behaviors, and the stimulation given to the infant during feeding. The observation categories utilized in the Feeding Observation included modified infant state, stimulation, latch-on, sucking, burping, and resting, and were defined prior to the Observation (Figure 2). We utilized a modified assessment of infant state for this observation. Wolff[11] originally described six states of arousal in term infants, which could be described clinically or by polygraph recording. In premature infants as compared to term infants, differentiation of states of sleep and awakening is more difficult, and state of arousal can change over a several second observation period.[10,12] We, like others, modified categories of infant state to facilitate rapid clinical assessment when polygraph recording is not performed.[10,13] Categories of infant oromotor behaviors were derived from a survey of available instruments and clinical experience.[13-15] The validity of sucking burst observation by nurse and mother observers has been previously established using comparison to electromyogram recordings of the orbicularis oris muscle.[4]

For each observation, lights were dimmed and ambient noise was minimized so that the infant could feed without interruption. The research nurse then observed the mother feeding her infant by either breast or bottle (the mother's choice). The Feeding Observation began when the nipple was first offered to the infant, and ended at 20 minutes, or when the nipple was no longer offered, whichever came first. At the start of the observation, and at precise 1 minute intervals, the nurse recorded a check under the appropriate modified infant-state category, and any behavior item that was occurring. Intake for bottlefed infants was determined by the amount in the bottle that was consumed by the end of the observation, and for breastfed infants by test weighing the infant on an electronic balance scale immediately before and after the observed feeding, which has been shown to accurately measure intake.[16] Postnatal and CAs at the time of the observation were noted.

Analysis of the Feeding Observation included both the absolute number of times each behavior was observed (behavior frequency), and the number of times each behavior was recorded as a percentage of the total time observed (behavior duration). Three summary categories were created: "any stimulation", "no stimulation", and "no latch-on". "Any stimulation" was the number or percent of observations during which the infant was receiving any of the interventions listed under "stimulation". Conversely, "no stimulation" was the number or percent of observations in which the infant received none of the listed interventions. "No latch-on" described the number or percent of observations in which none of the behaviors under the latch-on category were observed. Finally, duration of feeding and total intake for the feeding were recorded, and feeding efficiency, defined as milliliters per minute consumed over the time observed, was calculated.[17]

Maternal sociodemographic information, and infant birth and neonatal data were gathered prospectively. Nutritional intake was recorded daily while the infant was hospitalized, and included age of first and full enteral feeds, age of first bottle and breast feedings, and frequency of pumping and nursing at the breast. Relevant to this study, all mothers completed questionnaires

Definitions for Feeding Observation

Assessment Conditions: Lights dimmed and minimal ambient noise
Start time: Begin when nipple is first offered
End time: At 20 minutes, or when nipple is no longer offered, whichever comes first

INFANT STATE:
Awake alert: Eyes open or half open and bright
Drowsy: Eyes partially open or drooping and dull
Sleep: Eyes closed
Fussy: Fretful irregular movements with or without some crying
Crying: Active crying

STIMULATION:
Jiggle: Gentle repeated up and down or sideways movements of the baby (i.e. vestibular stimulation designed to maintain an alert state)
Swaddle: Wrap a blanket firmly about the body so as to enclose the extremities
Unwrap: Loosen or remove a blanket or layer of clothing
Elicit root: Stroke nipple across or next to mouth
Wiggle nipple: Repeatedly move the nipple up and down or sideways in baby's mouth, or in and out of mouth to elicit sucking

LATCH ON:
Rooting: Baby turns head (mouth) to nipple or to cheek stimulation
Mouth opening: Spontaneous mouth opening to nipple contact with or without rooting
Partial opening: As above, but the mouth is not open wide enough to admit the nipple without caregiver effort
No opening: No spontaneous effort or mouth opening on baby's part
Lick/nuzzle: Baby moves tongue over nipple or breast, or pushes face into nipple or breast
Partial seal: Baby's mouth encloses a part of areola and nipple and/or a gap visible, milk may drip, tongue may be elevated, retracted or flat
Complete seal: Baby's mouth encloses areola and nipple circumferentially and without gap

SUCKING:
Mouthing: Movements of baby's mouth on nipple without audible or visible swallowing
Single suck: Movement of baby's mouth on nipple accompanied by audible or visible swallow
Sucking burst: Two or more sucks in succession separated by less than 2 second pauses

BURPING: Infant is being held and patted or rubbed so as to elicit burp.
RESTING: Infant is being held quietly and nipple is not being offered.

Figure 2. Definitions for feeding observation.

including details of milk expression, nursing, bottle and formula feeding at 3 weeks chronologic age and at 35 weeks CA. Mothers who were breastfeeding reported the number of times they pumped each day, how many ounces were expressed each time, and the number of times the infant was put to breast daily.

Measures of neonatal morbidity included duration of oxygen and ventilator dependence, and presence of severely abnormal cranial ultrasound result, defined as Grade III or IV intraventricular hemorrhage, periventricular leukomalacia or ventricular dilatation at discharge. These measures were selected because chronic lung disease and neurologic abnormality have both been associated with poor sucking and feeding ability in premature infants.[18,19] In addition, a neonatal risk score was calculated for each infant and used as a summary of illness severity. This cumulative score, which we have used previously, is based on six neonatal risk factors.[20] The score ranges from 0 to 8 and is created by adding points for each neonatal risk factor as follows: apnea of prematurity = 1, septicemia = 1, jaundice of prematurity = 1, necrotizing enterocolitis = 1, chronic lung disease defined as oxygen dependence for 28 days (but not at 36 weeks CA) = 1, chronic lung disease defined as oxygen dependence at 36 weeks CA = 2, cerebral ultrasound abnormality defined as Grade I or II intraventricular bleed = 1, severe cerebral ultrasound abnormality defined as a Grade III or IV intraventricular bleed, periventricular leukomalacia or ventricular dilatation at discharge = 2.[20]

Statistical Analysis

We used the *t*-test to compare continuous measures and the χ^2 or Fisher's-exact test to compare categorical data. Non-normal continuous data were analyzed with the Mann–Whitney *U* test. Multiple regression (analysis of covariance) was performed for variables with normal or near normal distributions to adjust for factors that differed between the bottle-feeding and breastfeeding infants (maternal education and marital status). Behavior items (categories) with very few to no observations, meaning multiple scores were zero, were not compared. Spearman's rank-order correlation coefficient was used to assess the relationship between Feeding Observation behaviors and (1) maternal factors, including maternal age, educational level and marital status, (2) infant birth data and postnatal and CA at the time of the observation, and (3) measures of neonatal morbidity, including the neonatal risk score.

RESULTS

Mothers whose infants were observed breastfeeding reported pumping a mean of 6 ± 1.5 times per day, producing a mean of 110 ± 67 ml per pumping session, and putting the infant to breast a median of one time (range 0 to 4) per day. This information was obtained on the day of the feeding observation for most mothers (29 of 35, 83%) and within 2 days of the feeding observation for four additional mothers.

Table 1 Comparison of Bottle-Feeding and Breastfeeding Infants

Feeding observation	Bottle-feeding infants $n=70$	Breastfeeding infants $n=35$
Duration (mean minutes, SD)	13.8 (4.8)	13.3 (5.7)
Intake (median ml, range)	30.5 (4–75)**	6.5 (0–60)**
Efficiency in ml/minute (median, range)	2.2 (0.7–7.5)**	0.6 (0–3.0)**
Behaviors§		
State		
Alert¶	68%	50%
Drowsy¶	31%	43%
Stimulation		
No stimulation¶	33%	63%
Any stimulation¶	39%	38%
Elicit root	21%	19%
Wiggle nipple‖	18%	0%
Latch-on		
No latch	33%**	19%**
Partial seal‖	0%	7%
Complete seal¶	57%*	38%*
Sucking		
No sucking¶	33%	27%
Single suck	0%**	14%**
Sucking burst¶	55%**	33%**
Burping¶	19%**	0%**
Resting	6%	5%

*$p<0.05$.
**$p<0.001$ (bottle-feeding infants significantly different from breast-feeding infants by Wilcoxon Rank Sum test or by t-test as appropriate).
§Median percent of total time behavior was observed, median percent for all unlisted categories = 0%.
‖Unable to compare due to median of all observations = 0.
¶Variable with normal distribution; all others variables with skewed distribution.

Table 1 presents a comparison of the feeding observations of the 35 infants who fed at the breast with the 70 who fed by bottle. Breastfeeding as compared with bottle-feeding infants had a similar duration of feeding, but the bottle-feeding infants took in a greater volume of milk, and thus fed more efficiently. Bottle-feeding infants had more sucking bursts, less single sucks, more ''complete seal'' on the nipple, and spent significantly more time burping than breastfeeding infants. These differences remained significant after multiple regression analysis adjusting for maternal educational level and marital status.

We correlated infant feeding behaviors and maternal factors. For breastfeeding infants, higher maternal age was correlated with increased feeding efficiency ($r=0.366, p<0.05$) and more sucking bursts ($r=0.418, p<0.05$). Prior maternal breastfeeding experience, maternal educational level and marital status were *not* significantly correlated with feeding efficiency, intake volume, or any feeding behavior for breastfeeding infants. For bottle-feeding infants, single marital status was significantly correlated with shorter duration of feeding ($r=-0.237$), with less frequent complete seal at latch-on ($r=-0.251$) and with less frequent sucking bursts ($r=-0.264$, each $p<0.05$). Also for bottle-feeding infants, higher maternal educational level was significantly associated with longer duration of feeds ($r=0.338, p<0.01$), with more frequent sucking bursts ($r=0.265, p<0.05$) and with *lower* feeding efficiency ($r=-0.248, p<0.05$). There was no association of maternal age with feeding behaviors or efficiency for infants observed bottle-feeding.

We also correlated feeding behaviors with infant birth data and age at the time of the observation. For breastfeeding infants, there was no correlation between feeding performance or behavior and infant birth data or age at the time of the observation. Conversely, for bottle-feeding infants, feeding performance was significantly associated with infant factors in expected patterns. Higher birth weight was correlated with larger intake volume ($r=0.373$, $p<0.05$) and longer duration of feeding ($r=0.305, p<0.05$), and both higher birth weight and gestational age were correlated with more sucking bursts ($r=0.355$, $p<0.01$ and $r=0.244$, $p<0.05$, respectively). More mature postconceptional age was associated with better feeding efficiency ($r=0.263$, $p<0.05$) and less stimulation to feed ($r=-0.374, p<0.01$); more mature postnatal age was associated with shorter duration of feeding ($r=-0.274$, $p<0.05$).

Finally, we correlated feeding behaviors with neonatal morbidity, specifically duration of oxygen dependence, duration of ventilator dependence, neonatal risk score, and severely abnormal cranial ultrasound result. For breastfeeding infants, no measures of neonatal morbidity correlated with feeding efficiency or behavior. For bottle-feeding infants, increased duration of oxygen dependence and ventilator dependence were correlated with fewer sucking bursts ($r = -0.259$, $p < 0.05$ and $r = -0.254$, $p < 0.05$, respectively).

SIGNIFICANCE

Thus, breastfeeding as compared with bottle-feeding infants took in smaller volumes (median 6. 5 vs 30.5 ml, $p < 0.001$), fed less efficiently (median 0.6 vs 2.2 ml/min, $p < 0.001$), and spent less time with sucking bursts (mean 33 vs 55%, $p < 0.001$). The breastfeeding and bottle-feeding infants did not differ in age at the time of the observation, in birth data, in measures of neonatal morbidity, or in their neurodevelopmental status as measured by the Korner NAPI. Differences in feeding efficiency and performance remained after adjustment for maternal educational level and marital status using multiple regression analysis. Therefore, we conclude that feeding behavior and efficiency differ significantly for breastfeeding and bottle-feeding VLBW infants at 35 weeks CA.

Feeding efficiency is a measure of feeding performance that has not been previously applied to the breastfeeding infant. It is possible that the slower pace of intake associated with breastfeeding is actually beneficial for premature infants: better integration of breathing and swallowing is possible, and more time is spent in skin-to-skin or close contact with the mother, which may promote maternal attachment and infant development, as well as the enteromammary immune response.[1,21,22] However, volume of intake is a measure of feeding relevant to both bottle-feeding and breastfeeding infants, and was clearly lower in the infants observed breastfeeding. Others have similarly found low-intake volumes in larger preterm infants, which can be described as ''under-consumption'' at the breast, given the presence of measured adequate maternal milk production.[23,24]

Although these infants were still hospitalized at the time of the study, most preterm infants are being readied for discharge home at approximately 34 to 35 weeks CA. The pressure of managed care for prompt and early discharge is significant. There may be a subtle bias toward bottle-feeding in VLBW infants nearing discharge, because many practitioners believe that weight gain and full oral feeds, and hence discharge home, are more reliably achieved with bottle-feeding. Our data comparing feeding efficiency and volume of intake in breastfeeding and bottle-feeding VLBW infants support this clinical impression.

However, in nurseries where there is a culture of expectation of breastfeeding success, there was no significant difference in CA at discharge (36.4 weeks CA) between infants with full breastfeeding [57 (80%) of 71 infants] and those with no breastfeeding.[3] These may have been healthier preterm infants because the group was selected for study. However, another center reported that the breastmilk feeding VLBW infants were discharged at an earlier postnatal age than the formula feeding infants (mean 73 vs 88 days, $p = 0.03$).[25] Can intensive lactation intervention prior to 35 weeks CA increase feeding efficiency near the age of expected discharge? Or should intervention with the *goal* of full or partial breastfeeding be part of a home-going plan to permit discharge of infants who have achieved physiologic stability and adequate weight but not full oral feeds? What intervention would be most effective?

Evidence-based techniques for increasing maternal milk production and facilitating milk transfer during nursing of preterm infants have been reported. Frequent (5 to 8 times per day) milk expression with a simultaneous electric pump, the use of relaxation tapes, and pharmacologic methods including metaclopromide, have been shown to increase maternal milk supply in mothers of VLBW infants, and at least in larger preterm infants, adequacy of milk supply predischarge is crucial to achieving the transition to breastfeeding postdischarge.[26-31] The use of thin nipple shields significantly improves milk transfer.[32] Skin-to-skin contact (''kangaroo care'') by mothers of VLBW infants in hospital significantly increases duration of lactation and the number of mothers breastfeeding both 1 month postdischarge and at term.[8,33,34] Finally, the use of in-home test weighing after discharge may be helpful to nursing mothers of VLBW infants in providing reassurance of adequate intake as well as growth monitoring.[35]

We reported previously that successful lactation in mothers of VLBW infants at 40 weeks CA (term) was not correlated with infant birth factors or measures of neonatal morbidity including chronic lung disease, duration of ventilator dependence and severe cranial ultrasound.[8] In this study, we found that breastfeeding efficiency and performance at 35 weeks CA were not correlated with infant factors, including birth weight, gestational age, and similar measures of neonatal morbidity and risk. These findings support the working hypothesis that behavioral factors, rather than infant factors, are key to successful lactation and breastfeeding for VLBW infants.

Maternal correlates of feeding efficiency and performance differed between infants observed breastfeeding and those observed bottle-feeding. However, we let mothers select how to feed their infant for the observation, and 14 (20%) of the 70 mothers who bottle-fed for the observation were lactating and intended to breastfeed. This clouds analysis of maternal correlates of bottle-feeding behavior because sociodemographic factors are related to feeding choice.[8]

Strengths of our study include the large sample size, the inclusion of infants with risk factors for poor outcome and poor feeding ability, and the use of an observation scale that is appropriate for both breastfeeding and bottle-feeding premature infants. Other studies of feeding and sucking behavior of premature infants include smaller numbers of infants, infants of higher birth weights, or assess bottle-feeding or breastfeeding alone. The observation scale we used incorporates assessment of modified infant state, of infant oromotor skills, and of stimulation given during the feeding.

There are several differences between the Feeding Observation and the Premature Infant Breastfeeding Behavior Scale (PIBBS) used by Nyqvist to evaluate breastfeeding behavior.[3] First, the Feeding Observation can be used for both breastfeeding and bottle-feeding infants. Second, a nurse observer scores the Feeding Observation, while the mother rates her own breastfeeding session for the PIBBS. Finally, duration of the longest sucking burst is recorded in the PIBBS, while the number of sucking bursts is recorded in the Feeding Observation. It is not known which parameter, if either, is more predictive of breastfeeding success.

The major weakness of the study is the lack of formal reliability and validity testing for the Feeding Observation scale. Although the two research nurses who performed the observations used written behavior definitions and did 10 trial observations prior to the study, data on interobserver reliability was not formally collected. It has been previously demonstrated that direct observation of sucking behavior in VLBW infants is accurate and reliable, but data on interobserver reliability for modified infant state, latch-on behavior, and infant stimulation are needed.[4] Areas for future research include formal validation of the Feeding Observation scale, with repeated observations to assess its predictive value regarding time to full feeds by bottle or at breast.

In addition, we did not have mothers keep a daily milk expression log, although we did ask at 35 weeks CA [on the same day as the feeding observation (83%) or within 2 days (total of 94%)] how frequently mothers expressed milk and what volume of milk they produced. By written report mothers were expressing, and therefore had available in the breast, much more milk than their infants took in during the feeding observation. The median intake volume for the observed breastfeeding (6.5 ml) was $<10\%$ of the available milk (mean milk volume per pumping of 110 ml). We believe it is unlikely, but cannot exclude the possibility, that mothers' reports of their own milk expression were not accurate. Even if mothers overestimated their milk production by 100%, infant intake was still a fraction of the milk available. This concurs with what others have found.[23,32] Information regarding milk production should be documented prospectively in future work, and it may be helpful to ask mothers to express and measure their milk immediately following a nursing session.

In conclusion, we studied the feeding efficiency of 35 breastfeeding and 70 bottle-feeding VLBW infants at 35 weeks CA. Breastfeeding as compared with bottle-feeding infants consumed less milk, fed less efficiently, and had less sucking bursts. These data are concerning for discharge planning for infants whose mothers are planning to breastfeed partially or fully. However, performance of breastfeeding infants was not related to infant factors or neonatal morbidities, or to prior maternal breastfeeding experience. We thus speculate that strategies to improve breastfeeding efficiency of VLBW infants at 35 weeks CA will be applicable to all mother–infant breastfeeding couples regardless of the infant's medical history and the mother's breastfeeding experience. Trials with intensive and increased lactation support both before and after discharge are needed to improve feeding performance of breastfeeding VLBW infants nearing discharge.

Acknowledgements

This work was supported by the General Clinical Research Grant MO1 00080 from the National Institutes of Health. This work was partially funded by the Rainbow Babies and Children's Hospital Faculty Fund and the Rainbow Babies and Children's Hospital Board of Trustees. Sue Bergant, RN and Cathy Tasi, RN performed the feeding observations, and occupational therapists Angela Pace OTR/L and Sheri Ricciardi OTR/L administered the Korner Neurodevelopmental Assessment of the Premature Infant exams. We thank Maureen Hack, MBChB for guidance and support, and Eileen Stork, MD for manuscript review and discussion.

References

1. Meier P, Anderson GC. Responses of small preterm infants to bottle- and breast-feeding. Maternal Child Nurs 1987;12:97–105.
2. Martell M, Martinez G, Gonzalez M, Diaz Roselli JL. Suction patterns in preterm infants. J Perinatol Med 1993;21:363–9.
3. Nyqvist KH, Ewald U. Infant and maternal factors in the development of breastfeeding behavior and breastfeeding outcome in preterm infants. Acta Paediatr 1999;88:1194–203.
4. Nyqvist KH, Färnstrand C, Edebol Eeg-Oloffson K, Ewald U. Early oral behavior in preterm infants during breastfeeding: an electromyographic study. Acta Paediatr 2001;90:658–63.
5. Lau C, Alagugurusamy R, Schanler RJ, Smith EO, Shulman RJ. Characterization of the developmental stages of sucking in preterm infants during bottle feeding. Acta Pediatr 2000;89:846–52.
6. Gewolb IH, Schwietzer-Kenney EL, Taciak VL, Bosma JF. Developmental patterns of rhythmic suck and swallow in preterm infants. Dev Med Child Neurol 2001;43:22–7.
7. Medoff-Cooper B, McGrath JM, Shults JJ. Feeding patterns of full-term and preterm infants at forty weeks postconceptional age. Dev Behav Pediatr 2002;23(4):231–6.
8. Furman L, Minich N, Hack M. Correlates of lactation in mothers of very low birth weight infants. Pediatrics 2002;109(4) URL: http://www.pediatrics.org/cgi/content/full/109/4/e57.
9. Furman L, Taylor G, Minich N, Hack M. The effect of maternal milk on neonatal morbidity of very low birth weight infants. Arch Pediatr Adol Med 2003;157:66–71.
10. Korner AF, Thom VA. Neurobehavioral Assessment of the Preterm Infant Manual. The Psychological Corporation. New York, NY: Harcourt Brace Jovanovich, Inc., 1990.

11. Wolff PH. Observations on newborn infants. Psychosom Med 1959;21:110.
12. Hack M. The sensory development of the preterm infant In: Fanaroff AA, Martin RJ editors. Behrman's Textbook of Neonatal–Perinatal Medicine. 5th ed. St. Louis: CV Mosby, 1991.
13. Nyqvist KH, Rubertsson C, Ewald U, Sjoden P. Development of the preterm infant breastfeeding behavior scale (PIBBS): a study of nurse–mother agreement. J Hum Lact 1996;12:207–19.
14. Matthews MK. Assessments and suggested interventions to assist newborn breastfeeding behavior. J Hum Lact 1993;9:243–8.
15. Palmer MM, Crawley K, Blanco IA. Neonatal oral-motor assessment scale: a reliability study. J Perinatol 1993;13:28–35.
16. Meier P, Lysakowski Y, Engstron JL, et al. The accuracy of test weighing for preterm infants. J Pediatr Gastroenterol Nutr 1990;10:62–5.
17. Lau C, Sheena HR, Shulman RJ, Schanler R. Oral feeding in low birth weight infants. J Pediatr 1998;132:560–1.
18. Gewolb IH, Bosma JF, Taciak VL, Vice FL. Abnormal developmental patterns of suck and swallow rhythms during feeding in preterm infants with bronchopulmonary dysplasia. Dev Med Child Neurol 2001;43:454–9.
19. Katz-Salamon M, Albert K, Bergstrom BM, et al. Perinatal risk factors and neuromotor behavior during the neonatal period. Acta Paediatr Suppl 1997;419:27–36.
20. Taylor HG, Klein N, Schatschneider C, Hack M. Predictors of early school age outcomes in very low birth weight children. Dev Behav Pediatr 1998;19:235–43.
21. Goldman AS, Thorpe LW, Goldblum RM, et al. Anti-inflammatory properties of human milk. Acta Pdiatr Scand 1986;75:689–95.
22. Feldman R, Eidelman AI. Direct and indirect effects of breastmilk on the neurobehavioral and cognitive development of premature infants. Dev Psychobiol 2003;43:109–19.
23. Hurst NM, Meier PP, Engstrom JL, et al. Milk volumes consumed at breast during the first month post-discharge (PDC) for preterm infants (PI): implications for management of breastfeeding and infant growth. Pediatr Res 2000;47:197A.
24. Woolridge J, Hall WA. Posthospitalization breastfeeding patterns of moderately preterm infants. J Perinat Neonatal Nurs 2003;17:50–64.
25. Schanler RJ, Shulman RJ, Lau C. Feeding strategies for premature infants: beneficial outcomes of feeding fortified human milk vs preterm formula. Pediatr 1999;103:1150–7.
26. Auerbach KS. Sequential and simultaneous breastpumping: a comparison. Int J Nurs Stud 1990;27:257–65.
27. Hill PD, Aldag JC, Chatterton RT. The effect of sequential and simultaneous breastpumping on milk volume and prolactin levels: a pilot study. J Hum Lact 1996;12:193–9.
28. Ehrenkranz RA, Ackerman BA. Metaclopromide effect on faltering milk production by mothers of preterm infants. Pediatrics 1986;78:614–20.
29. Gunn AJ, Gunn TR, Rabone DL, Breier BH, Blum WF, Gluckman PD. Growth hormone increases breastmilk volumes in mothers of preterm infants. Pediatrics 1996;98:279–82.
30. Ruis H, Rolland R, Doesburg W, Broeders G, Corbey R. Oxytocin enhances onset of lactation among mothers delivery prematurely. BMJ 1981;283: 340–2.
31. Feher SD, Berger LR, Johnson JD, Wilde JB. Increasing breastmilk production for premature infants with a relaxation/imagery audiotape. Pediatrics 1989;83:57–60.
32. Meier PP, Brown LP, Hurst NM, et al. Nipple shields for preterm infants: effect on milk transfer and duration of breastfeeding. J Hum Lact 2000;16:106–14.
33. Bier JA, Ferguson AE, Morales Y, et al. Comparison of skin-to-skin contact with standard contact in low-birth-weight infants who are breast-fed. Arch Pediatr Adol Med 1996;150:1265–9.
34. Whitelaw A, Heisterkamp G, Sleath K. Skin to skin contact for very low birthweight infants and their mothers. Arch Dis Child 1988;63:1377–81.
35. Hurst NM, Meier PP, Engstrom JL, Myatt A. Mothers performing in-home measurement of milk intake during breastfeeding of their preterm infants: maternal reactions and feeding outcomes. J Hum Lact 2004;20:178–87.