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Co-regulated Approach to Feeding Preterm Infants with Lung Disease: Effects During Feeding

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Abstract

Background—Very preterm infants are at risk for poor oral feeding endurance, early cessation of eating, poor fluid management with aspiration risk, behavioral distress, and unstable heart rate and oxygenation during feeding.

Objective—To determine the preliminary effectiveness of a Co-Regulated Approach (CoReg) to oral feeding for very preterm infants at risk for lung disease.

Method—A randomized, within-subjects, cross-over design was used with 20 very preterm infants requiring oxygen at the start of oral feeding. Infants were bottle fed by the Usual Care approach and by the CoReg approach on 2 consecutive days for an average of four feedings each. Intervention components included co-regulation of suck, swallow, and breathe rhythms using enhanced auditory assessment, infant-guided feeding onsets, and infant positioning in a semielevated, side-lying position. Infant physiology metrics (heart rate, SaO₂) were collected

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continuously prior to and during the feeding. Behavioral and auditory indicators of regulation were coded continuously from videotape during the feeding.

Results—Seventy feedings were analyzed (38 Usual Care, 32 CoReg) using repeated measures modeling. CoReg feedings were characterized by more frequent preparation of the infant for the feeding, were more commonly initiated in response to infant readiness cues, had more rest periods and breath regulation events, and had fewer sucking stimulation events. CoReg feedings had less SaO₂ variability, decline, and time spent in a desaturated state; less heart rate fluctuation and decline; less behavioral disorganization; better fluid management; and less observed effort to breathe.

Discussion—Support is provided for a co-regulated approach to feeding vulnerable infants. Enhanced auditory assessment of infant feeding rhythms increases the responsiveness of the feeder and improves infant behavioral and physiologic responses.

Keywords

preterm infant; breathing; feeding behavior

Very preterm (VP) infants, defined as those < 32 weeks gestational age, are at risk for impaired pulmonary function (Friedrich, Stein, Pitrez, Corso, & Jones, 2006), which, in turn, creates significant physiologic challenges during oral feeding (Craig, Lee, Freer, & Laing, 1999; Gewolb & Vice, 2006a; Goldfield, 2007; Mizuno et al., 2007). Feeding difficulties begin early, when oral feedings are first introduced, and have a negative impact on developing early feeding skills, growth, and length of hospitalization (Dodrill, Donovan, Cleghorn, McMahon, & Davies, 2008; Pickler, Best, & Crosson, 2009; Sakurai, Itabashi, Sato, Hibino, & Mizuno, 2008).

Very preterm infants have difficulty organizing the suck-swallow-breathe sequence. Poor coordination creates the conditions for fluid threats to the airway, extended airway closure, and a pattern of insufficient rate and depth of breathing. Disrupted breathing and fluid threats during feeding affect the infant's quality of sucking and behavioral responses (Mizuno et al., 2007; Thoyre & Carlson, 2003). As a consequence, many VP infants demonstrate poor endurance, early cessation of feeding, poor fluid management with aspiration risk, periods of behavioral distress, and unstable oxygenation and heart rate.

Feeding dynamics theory, based on developmental dynamic systems theory, explains that early feeding performance is an emergent property of multiple interacting subsystems involved in feeding (Goldfield, 2007; Lewis, 2000; Thelen & Smith, 1994). Within the infant, physiologic functioning, particularly the preterm infant's altered pulmonary functioning and immature neurological system, limits the infant's capacities. External to the infant, the co-regulatory competence of the caregiver further constrains the infant's performance.

Very preterm infants adopt several behavioral patterns during oral feeding to protect their airway while trying to meet the goal of nutritional intake sufficient for growth. Younger, less mature, and less healthy infants often adopt a suck-swallow-breathe pattern in which sucking and swallowing alternate with breathing; essentially uncoupling the coordination of the three

(Gewolb & Vice, 2006b; Vice & Gewolb, 2008). This pattern requires less coordination, but it can be problematic. The sucking burst can be too long, creating too long of a pause in breathing and drawing too large a bolus of milk into the mouth which may require multiple swallows to clear (Mathew, 1991). These swallows will further prolong the interruption in breathing. Moreover, when sucking and swallowing stops and breathing ensues, the breaths can be insufficient in depth or rate to restore oxygen deficits (Craig et al., 1999). When the potential problems associated with this pattern are understood and assessed, the caregiver can use this feedback to select co-regulation strategies to improve feeding outcomes. Sucking bursts that are too long for the individual infant can be abbreviated, shifting the infant to the breathing phase. Alternatively, the breathing phase can be prolonged by keeping the nipple stimulus from the infant until their ventilation needs are met (Law-Morstatt, Judd, Snyder, Baier, & Dhanireddy, 2003).

Very preterm infants may self-regulate also by sucking with shorter bursts, allowing for more breathing time. While adaptive, sucking with shorter bursts delays the establishment of longer sucking runs (Gewolb & Vice, 2006a) and prolongs the duration of the feeding. Consequently, caregivers often try to override infant responses by stimulating more sucking (Kaye & Wells, 1980). For VP infants, who are dealing with poor oxygen reserves and less functional lungs than term infants, promoting more sucking may jeopardize safe swallowing and adequate respiration. An alternative approach is to support infants' self-regulation efforts and steer away from encouraging sucking, thus helping the infant pace his or her energy, engage in sufficient breathing, and protect his or her airway.

A co-regulated approach to feeding (CoReg) focuses on interpretation of infants' functional adaptations during feeding with a goal to assist infants to regulate timing relationships among sucking, swallowing, and breathing more effectively. The purpose of the present study was to determine the preliminary effect of CoReg on feeding outcomes (physiologic stability, behavioral organization, fluid management, and work of breathing) for VP infants at risk for lung disease. The effect of the CoReg approach on the length of time to feed and nutritional intake, both outcomes that are important for nurses, was explored also.

Individualized Co-Regulation of Feeding

CoReg was developed to enhance assessment of infant feeding adaptations and provide appropriate response to common coordination patterns. In response to behavioral, auditory, and physiologic feedback from the infant, the caregiver provides rest periods and opportunities for breathing, decreases the flow of milk by adjusting the sucking burst length, responds to loss of milk at the lips with rest periods that allow for reorganization of infant swallowing function, and decreases the feeding demand at early signs of behavioral disorganization, allowing the infant to reorganize at the behavioral level. An innovative component of the intervention is to sensitize the caregiver to the infant's breathing and swallowing rhythms by placing a small microphone on the infant's neck (the audio trainer[®]). The sounds of breathing and swallowing are transmitted to the caregiver via an earpiece. It was hypothesized that these amplified cues would enhance understanding of the infant's coordination patterns and the caregiver's ability to respond to the infant throughout the feeding. In addition to individualized co-regulation, the CoReg feeding approach sets the

stage for success during feeding by implementing principles of developmental care, including elevated side-lying positioning with postural support; preparation of the infant prefeeding; initiation based on infant readiness; and minimization of movement during feeding and burping.

Acoustic enhancement of the sound of breathing and swallowing

Enhancing the sounds of feeding is advocated as a clinical assessment technique for vulnerable infants (Rogers & Arvedson, 2005) and used as a measurement strategy in studies examining the coordination of sucking, swallowing, and breathing (Goldfield, Richardson, Lee, & Margetts, 2006; Vice, Bamford, Heinz, & Bosma, 1995; Vice, Heinz, Giuriati, Hood, & Bosma, 1990).

Co-regulating infant sucking, swallowing, and breathing rhythms

Co-regulation has been described as “pacing” or “regulating” (Law-Morstatt et al., 2003; Palmer, 1993; VandenBerg, 1990). Rosen, Glaze, and Frost (1984) first noted in their early study of hypoxemia during feeding of vulnerable infants that interrupting the infant’s sucking when his or her breathing became irregular resulted in resumption of regular breathing and increased oxygen levels. Law-Morstatt et al. examined the effect of receiving “paced feedings” throughout the oral feeding learning period in the neonatal intensive care unit with a sample of infants diagnosed with respiratory distress syndrome or chronic lung disease. In Law-Morstatt’s study, pacing was prescribed every 3 sucks or every 3-5 sucks, dependent on individual infant sucking assessments. Compared to nonpaced feedings, paced infants demonstrated more organized sucking patterns at discharge and had fewer bradycardic events during a randomly selected subset of feedings.

CoReg differs from paced feeding in several key ways. CoReg is individualized throughout the feeding, dependent on the infant’s ability to breathe with sufficient rate and depth and to swallow safely. Since early feeding skill is dynamic with high variability in coordination (Goldfield, 2007; Handford, Davids, Bennett, & Button, 1997), co-regulative strategies need to be dynamic, providing more support when the infant is less self-regulative and less when the infant demonstrates the ability to self-regulate. Further, CoReg feeders aim to not only respond to the infant’s need for additional breathing or reorganization but also to learn about the infant’s pattern of breathing and signals of dysregulation so that feeding rhythms can be co-regulated proactively. This requires understanding the meaning of infant feeding sounds and patterns of adaptation, and selection of feeding strategies that are sensitive to infant need.

Positioning the infant in a semi-elevated side-lying position

Side-lying during oral feeding is theorized to offer several benefits. First, breast feeding commonly occurs in a side-lying position. Since many preterm infants who are learning to oral feed are offered both breast and bottle feeding opportunities, feeding the VP on his or her side will bring consistency across feeding conditions, constrain the dimensions of the problem space, and facilitate the infant’s discovery of effective motor solutions (Handford et al., 1997). Second, the oral transit time of milk from the oral cavity to the esophagus is influenced by gravity; the side-lying position may afford the infant more time to form a

bolus and swallow with increased efficiency. More efficient swallowing in a side-lying position may allow infants with higher respiratory rates more opportunity for breaths. Finally, respiratory mechanics and pulmonary function may be affected by position (Dean, 1985). In an upright position, preterm infants, particularly those of younger gestational age or with tachypnea, are prone to head flexion, hypoxemia, and apnea (Ojadi, Petrova, Mehta, & Hegyi, 2005). Semi-upright positioning with careful positioning diminishes the risk for head flexion, but gravity places the preterm at risk for downward displacement of the epiglottis and overall decrease in laryngeal area. Two pilot-sized preterm feeding studies have found oxygenation improves in prone (Mizuno, Inoue, & Takeuchi, 2000) and semi-elevated, side-lying (Clark, Kennedy, Pring, & Hird, 2007) compared to semi-upright positions.

Method

Infants were compared against their own performance in a within-subject, cross-over design comparing the Usual Care feeding approach with the CoReg approach; infants were randomized to which approach was ordered first. The study took place during the 8 am to 5 pm feedings across 2 days; therefore, infants could be fed by either approach up to three times each day.

Participants

The study took place in a level III neonatal nursery in the southeast United States when infants reached the ability to ingest half of their intake orally. To be eligible for the study, infants needed to be less than or equal to 1500 grams at birth (BW), less than 33 weeks gestation (GA), of appropriate weight for age at birth, and requiring supplemental oxygen at the time oral feedings began. Infants with other conditions or medical problems that may interfere with sucking were excluded, such as cleft palate, Down syndrome, a history of necrotizing enterocolitis, or grade IV intraventricular hemorrhage (IVH). To provide consent, mothers needed to be 18 years of age or older and able to understand English.

Usual Care Feeding Protocol

On the Usual Care feeding day, infants were fed using a time-based schedule (typically every other feeding at the time of the study). The nurse scheduled to care for the study infant or a family member familiar with bottle feeding the infant, bottle fed the infant; at times nurses provided an oral feeding off schedule based on their judgment of infant readiness. Usual Care feeders were encouraged to stop and start, move the infant around, and speak to the infant as normal. They were also told that the researchers would not speak to them or the infant or make eye contact during the study period. If a family member fed, the researchers reminded him or her that the infant's nurse would provide consultation as needed.

CoReg Intervention Protocol

On the CoReg feeding day, a research team member (trained nurse or speech pathologist) fed the infant using the intervention protocol (Table 1). Feedings were offered during the nursery's scheduled feeding times contingent on infant readiness (i.e., no set time-based schedule) as per McCain's (2003) recommendations. During the bottle feeding, the CoReg

feeder wore a single earphone transmitting the breathing and swallowing sounds from the microphone placed on the infant's neck.

Physiologic Measures

Oxygen saturation (SaO₂) and heart rate (HR) were collected using an Ohmeda 4700 pulse oximeter (Boulder, CO) and a Gould electrocardiogram (ECG) monitor (Valley View, OH). All physiologic data were recorded with WINDAQ data-acquisition software (DATAQ Instruments, Inc. Akron, OH) on a laptop computer. Physiologic data was digitized and cleaned of artifact using the pulse wave from the oximeter and the ECG HR pattern to detect movement or loss of sensor contact. Prefeeding baseline data were calculated for SaO₂ and HR for each feeding observation during a time when the infant was quiet and not sucking on a pacifier. Within each feeding condition, SaO₂ variables included mean, minimum, and percent of time below 85%, and HR variables included mean, minimum, and maximum. Stability of SaO₂ and HR within each feeding was assessed using coefficients of variation (standard deviation and mean). When an infant was exposed to a feeding condition more than once, the means and standard deviations (SD) of the SaO₂ and HR were pooled for the feeding condition and the coefficients of variation were calculated using the pooled data.

Observational Measures

All feeding observations were videotaped. Audible and observable markers of infant regulation were coded from the videotaped observations using the Observer software program (Noldus Information Technology Inc., Asheville, NC) and the Dynamic-Early Feeding Skills (D-EFS) coding system developed by Thoyre (2009). All periods of the feeding observation with the bottle in the mouth were coded continuously. Markers of infant dysregulation included the proportion of the bottle-in feeding periods with behavioral disorganization, disorganized fluid management, and increased work of breathing. Sounds transmitted from the microphone to the video camera augmented coding of fluid management and work of breathing (see Table 2 for code descriptions).

Feeding Length and Intake Measures

Length of feeding was recorded from initial insertion of the nipple until final removal of the nipple, to the nearest second using the time on the videotape. A second variable, the number of total seconds the bottle nipple was in the infant's mouth (i.e., the suckling period; rests and burping periods removed), was calculated also using the time on the videotape. Caloric intake was assessed by measuring the total volume in milliliters of formula or breast milk consumed over the length of feeding, using a standard measuring cup before and after the feeding. The burp cloth was weighed before and after the feeding and the amount of spilled milk was subtracted from the total volume using the formula of one gram weight of the cloth equal to one milliliter milk spill. Since the infant's prescribed intake is based on weight, the percent of the infant's prescribed intake ingested was calculated also.

Fidelity Measures

To determine fidelity to the intervention protocol and to examine the extent to which the Usual Care feedings were similar to the CoReg feedings, caregiver behaviors during the

feeding were coded continuously during the bottle-in periods. These variables included the proportion of the feeding the infant was positioned semi-upright compared to semi-elevated side-lying, proportion of feeding onsets (each bottle in) with preparation of the infant prior to nipple placement (defined as rooting and waiting for infant seeking of the nipple), infant readiness at the time of each nipple placement (defined as opening mouth and dropping tongue to receive the nipple when the nipple is presented at the lips), the number of rest periods provided with the bottle out of the mouth, the number of times the flow of milk was stopped to allow for the infant to swallow and resume a pattern of breathing, and the number of times the infant received stimulation that could cause them to increase sucking (e.g., jiggling the nipple).

Coders for all observational measures were blinded to the study purpose and feeding type (Usual Care vs. CoReg) and were trained to 85% agreement and kappa of at least .70 on each code. Interrater reliability was assessed using 20% of the feeding observations. Cohen's kappas for the infant regulation codes ranged from .76 to .79, with a mean of .78. Cohen's kappas for the intervention fidelity codes ranged from .77 to .93, with a mean of .84.

Procedure

The research protocol and consent forms were approved by the Institutional Review Board at the University of North Carolina at Chapel Hill. Informed consent was obtained from the infant's mother and from the assigned nurse after the nature of the study procedures had been explained fully. Infants were enrolled when they began oral feeding and participated in the study when they were able to oral feed half of their prescribed feeding volume in a 24-hour period. Therefore, infants varied in postmenstrual age and experience eating at the time of study but were similar in feeding skill. The researchers aimed to observe all bottle feedings that fell between 9 am and 6 pm on two consecutive days. Because the demands of breast feeding are significantly different from those of bottle feeding and not all infants breast fed, researchers asked that the infant only receive bottle feedings during the study's observed oral feedings.

Each study day, following an 8 am gavage feeding, and prior to settling the infant for the interfeeding rest period, all instruments were placed that required handling of the infant (pulse oximeter sensor, ECG sensors, audio trainer[®] microphone). The audio trainer[®] was placed lateral to the infant's trachea and posterior to the infant's jaw line and was adhered with double-sided tape. Researchers remained available to videotape and collect physiologic data on all feedings that occurred through 6 pm that evening—whether bottle fed by nurse, family member, or CoReg study team.

During the time of the study, infants were fed every 3 hours; therefore, each infant had the potential of being fed three times during each study day, for a total of six feedings each. The standard nursery standard-flow bottle nipple was used throughout the study, as was customary in the nursery at this time. Since nipples vary in flow rate, the same standard-flow nipple was washed and reused for all bottle feedings across each individual infant's two study days. The bottle, with the amount and content of formula or breast milk corresponding to the infant's medical orders, was warmed per nursery protocol. As is standard practice, all caregivers had visual access to the cardiorespiratory and oxygen saturation monitors

throughout the feeding. Each feeding was videotaped using the camera focused on the infant's face and upper body. While the audio trainer[®] transmitted sound to the camera for all feedings, only the CoReg intervention feeders wore the earpiece during the feeding.

Analyses

All analyses were run with SAS software version 9.1 (Cary, NC). *A priori* power analyses using feeding day nested within infant as the unit of analysis indicated that, for a two-sided significance level of 0.10, 21 infants with complete data would provide power exceeding 75%. This resulted in a mean difference of 0.53 standard deviations (where standard deviation is calculated for a particular feeding day, not for the within-infant difference) between the Usual Care and CoReg feedings; this effect size was chosen based on pilot data. The correlation parameter between adjacent observations is assumed to be at least .5; correlations smaller than this seemed unlikely for physiological parameters measured one day apart. With only $n = 20$ infants available for analysis, the corresponding power decreases slightly to 74%.

All analyses of fidelity to the intervention protocol, outcomes, and comparison of prefeeding measures used repeated measures modeling via mixed effects models (PROC MIXED) to take into account the correlation of the feeding observations within the same infant (i.e., the unit of analysis is each feeding day, nested within each infant). Chi-squared tests from generalized estimating equations (GEE) models were used to compare the proportion of feeding periods beginning with infant preparation and readiness (each assessed as *yes* or *no*) for Usual Care and CoReg feedings. For the GEE models, the unit of analysis is each feeding, nested within each feeding day, further nested within each infant. Coefficients of variation were analyzed using Wilcoxon signed-ranks tests. Since this was an early phase study, the significance level was set at .10 (two-sided).

Results

Twenty-one infants were recruited for the study; 1 infant subsequently was removed due to illness (Table 3). Of the 20 remaining infants, 14 were female, 11 were African American, 7 were Caucasian, and 2 were Asian American. At discharge, 3 infants were diagnosed with respiratory distress syndrome, and 17 infants had a diagnosis of bronchopulmonary dysplasia (BPD) using the National Institutes of Health consensus definition (Jobe & Bancalari, 2001); 7 infants met the definition of mild BPD, 4 moderate, and 6 severe. One infant had Grade 3 IVH, 5 infants had Grade 1 IVH, and the remaining 14 infants had no evidence of IVH.

There were a total of 75 feeding observations: 40 Usual Care and 35 CoReg. Over the course of the 2-day study, each infant was fed, on average, four times; twice by the Usual Care and twice by the CoReg approach. During the Usual Care feedings, the nurse elected, either due to infant nonreadiness or to adhere to the time-based feeding schedule, not to feed the study infant a total of 12 times. In addition, one Usual Care feeding became a breast feeding (eliminating it as a study feeding) because the mother had had little opportunity to breast feed her infant up to this day. During the CoReg feedings, the intervention feeder elected not

to feed the study infant due to nonreadiness a total of 18 times. Consequently, there are more Usual Care feedings than CoReg feedings.

Carryover of the intervention effects from one day to the next were not theoretically likely. Nonetheless, the sequence of the two feeding conditions within an infant was selected randomly using a simple coin toss to help provide balance in the order of the feeding conditions across subjects. Ideally, half of the infants would receive the Usual Care feeding condition on day 1 and the other half would receive the CoReg feeding condition on day 1. However, clinical situations arose from time to time that necessitated a change in plans. The most common scenario involved the nurse being unable to feed the infant due to competing demands in the unit. In these situations, another nurse was sought to do the feeding, and if none was available, an intervention feeding was provided. These were random and unplanned changes in the design; nonetheless, more Usual Care feedings occurred on Day 1 of the study and more CoReg feedings occurred on Day 2. Therefore, an order effect was tested for and the order of feeding by study day was not found to impact any outcome variable significantly.

Five feedings (2 Usual Care, 3 CoReg) were too short to include in outcome analyses because the nipple was in the infant's mouth for less than 2 minutes. A total of 70 feedings were eligible: 38 Usual Care feedings and 32 CoReg feedings. In addition, 4 Usual Care feeding observations had unusable heart rate data; therefore, 34 Usual Care feedings were compared to 32 CoReg feedings on heart rate variables.

Intervention fidelity

Caregiver behaviors were coded in the laboratory to validate whether the intervention was carried out as specified. For this analysis, all feeding observations were included, even those that were deemed too short for outcome analysis (Tables 4 and 5). These data demonstrate that the intervention feedings predominantly occurred with the infant in a side-lying position ($p < .001$). In the intervention condition, infants were more likely to be prepared prior to nipple insertion ($p < .001$) and to have the nipple placed after demonstrating readiness for the nipple ($p < .001$), and were given significantly more rest periods ($p = .003$) as well as opportunities for the infant to quit sucking and resume a pattern of breathing (Cue Stop; $p < .001$). In addition, significantly fewer stimulation events occurred in the CoReg condition ($p < .001$); all providing evidence of adherence to the intervention protocol.

Physiologic stability

Infants fed by the CoReg feeding approach had less physiologic instability during feeding. Groups were comparable on prefeeding SaO₂ and HR (Table 6). During the feeding period, CoReg feedings had a slightly higher mean SaO₂ that was not clinically or statistically significant. Less severe SaO₂ decreases during the feeding occurred with the CoReg approach ($p = .089$) and less time was spent with SaO₂ < 85% ($p = .022$). Compared to the Usual Care group, CoReg feedings had significantly less severe HR decline during the feeding period ($p = .002$) and higher mean HR ($p = .037$), however, the difference in mean HR (165.54 vs. 162.68) was not clinically significant and was likely a result of fewer HR declines in the CoReg group. The CoReg group had smaller medians in coefficient of

variation for SaO₂ (0.034 vs. 0.042, $p < .001$) and HR (0.045 vs. 0.074, $p = .006$) compared to the Usual Care group, respectively.

Behavioral organization, fluid management, and work of breathing

Infants fed using the CoReg feeding approach demonstrated greater feeding regulation as measured by the observational variables (Figure 1). The percentage of the feeding period with behavioral disorganization was diminished (15.62 vs. 26.91; $p < .001$). Disorganized fluid management was diminished (21.08 vs. 48.61, $p < .001$), as was the percentage of the feeding when the infant had observable or audible increase in the work of breathing (20.26% vs. 34.66%; $p < .001$).

Length of time to feed and nutritional intake

Feedings varied in length within each group (Table 7). The difference between the total length of the feedings ($p = .216$) and between the length of the suckling periods ($p = .389$) was not statistically different between the groups. Caloric intake was statistically different between groups, but not clinically significant, with the Usual Care group taking, on average, 38.9 compared to 34.5 milliliters per feeding ($p = .024$) (Table 7). However, the difference between the proportion of the infant's prescribed volume of intake was not statistically different between the groups ($p = .556$).

Discussion

This study provides evidence for the preliminary effectiveness of an approach to oral feeding of infants at risk for lung disease. The short-term, within-feeding outcomes of the CoReg feeding approach as provided by a trained feeder were tested. CoReg feeders prepared infants for feeding more often and were more likely to initiate feedings when infants demonstrated readiness. Breathing and swallowing was co-regulated more often, as evidenced by more frequent bottle tip backs that serve to cue the infant to stop sucking, initiate swallowing, and resume breathing. CoReg feeders also provided more rest periods and kept the infant more organized and calm. Further, infants fed with the CoReg feeding approach had less observable work of breathing, managed milk with less fluid sounds in the airway and less loss of fluid at the lips, and had more stable SaO₂ and HR throughout the feeding than the same infants fed by Usual Care.

Co-regulating sucking, swallowing, and breathing by tipping the bottle back was not difficult; its frequency varied both between and within feedings. This highlights the need for a flexible and dynamic approach to feeding with enhanced auditory assessment throughout the feeding. Some infants did not respond to tipping the bottle back with cessation of sucking; rather, the nipple stimulus needed to be removed completely. Although CoReg feeding assisted the infant to maintain more physiologic stability (less variation in SaO₂ and HR), the aim is to maintain the infant's SaO₂ even closer to their prefeeding level. In reviewing the videotapes, the co-regulation strategies could be improved (i.e., tip the bottle back sooner and more often). With more experience with each infant, skill at co-regulation likely would improve and the infant would learn to be more self-regulative with consistent and predictable feedings. This warrants further testing.

This is the first study to test enhanced auditory feedback as a feeding strategy. Listening to infants' feeding sounds is a means of learning about individual infants' patterns of coordination. Once the infant's coordination patterns are understood, it is likely that the need for enhanced audio feedback would diminish; the use of the audio trainer[®] would be a time-limited device to individualize infant care and to teach nurses and parents about infants' feeding needs. This will require further study.

Limitations

Limitations of this study include the relatively small sample size and testing a multiple component intervention. A larger sample and replication would increase confidence in these findings. Because of the multicomponent intervention, it is not possible to determine the effect of any one component separate from the others. While it is believed that feeding high-risk infants requires a comprehensive approach that uses all of the specified intervention components, more study is warranted to understand the effect of each component.

Clinical Implications

The sensitivity of the caregiver's response during feeding depends on the feedback they receive from the infant and the meaning they attach to that feedback. Clinical practice can be changed by amplifying the feedback the infant provides. The Usual Care feeding practices in this study were not believed to be atypical of feeding care in many current nurseries. Several of the strategies (most notably, preparing the infant for feeding; co-regulating breathing; and using infant behaviors to determine when to initiate, provide rests, and end the feeding) are recommended widely as components of developmental care. Nurses providing Usual Care feedings would be expected to use these strategies more frequently; however, co-regulatory bottle tip backs rarely occurred and over half of the feeding initiations in the Usual Care feedings began without infants providing readiness cues.

When an infant is ready to feed and interested they will seek the nipple when it is presented, organize their tongue to receive it, and orient their body posture midline with arms coming forward to assist. This set of behaviors is an indication of neurodevelopmental readiness to feed (Shaker, 1990). When the caregiver uses strategies to enhance the conditions for participation (e.g., repositioning), prepares the infant by using rooting to assess readiness, and waits for an active response, the infant is given the opportunity to be a full participant in the feeding and active participation is a central feature of learning a new skill (Rogoff, Baker-Sennett, Lacasa, & Goldsmith, 1995).

Infant behavior also guides the caregiver to know when to provide rest periods and when to support the infant's self-regulation of breathing. CoReg feeders responded to early indicators of fatigue and behavioral distress by removing the nipple stimulus, rather than by encouraging sucking. Pauses in sucking were not interrupted; rather, they were regarded as self-regulative and as opportunities for the infant to recover his or her breathing.

Conclusion

A co-regulated feeding approach has significant short-term benefits. CoReg feeders more often prepared infants for feeding and initiated feedings in response to infant readiness cues.

Through auditory assessment of feeding, the feeders co-regulated breathing and swallowing more often, provided more rest periods, and kept the infant more organized and calm than the Usual Care feeders. Further, CoReg feeders were able to decrease the infant's work of breathing, stay within the infant's capacity to transfer milk efficiently, and keep the infant's SaO₂ and HR more stable with less significant declines. Questions remain whether the CoReg approach has long-term benefits. Theoretically, the CoReg approach would be optimized by repeated exposure (i.e., positive and predictable experience) from the beginning of oral feeding. This could be tested by examining longer-term outcomes such as time to full oral feeding, time to discharge, and growth during the final weeks of hospitalization. In addition, since approximately a third of these high-risk infants will develop feeding problems postdischarge, the CoReg approach needs to be tested with parents using the approach with long-term development of feeding skills and feeding problems as additional outcomes.

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Figure 1.
Percentage of the bottle-in periods with observational indicators of feeding dysregulation.
All at $p < .001$.

Table 1**CoReg Feeding Approach Protocol**

-
- Hold the infant in a head elevated side-lying position in a flexed-body position (shoulders adducted, hips and knees flexed).
 - Provide minimal movement of infant's body.
 - Avoid any prodding techniques to encourage sucking or movements of the nipple that may increase dripping from the nipple.
 - Place nipple into infant's mouth at outset and after each nipple removal only after infant opens their mouth and drops tongue to receive the nipple. The feeding is considered completed when the infant no longer seeks the nipple after it had been offered several times.
 - When infant has not had sufficient number or depth of breath in relation to their pre-feeding respiratory rhythm, move the nipple of the bottle to the roof of the infant's mouth and tip bottle down to prevent milk dripping and to cue the infant to swallow and breathe. If infant does not respond with cessation of sucking and resumption of breathing, remove the nipple from the infant's mouth.
 - Move the nipple of the bottle to the roof of the infant's mouth and tip the bottle down if breaths are interrupted, restricted or if the work of breathing has increased indicated by nasal flaring, color change, or accessory muscle use. If infant does not respond with cessation of sucking, remove the nipple from the infant's mouth. Rest infant until breathing work resumes the pre-feeding quality, with baseline color and no use of accessory muscles.
 - If infant spills milk out of mouth or if fluid sounds are audible in the airway, move the nipple of the bottle to the roof of the infant's mouth and tip the bottle down. If infant does not respond with cessation of sucking, remove the nipple from the infant's mouth.
 - Respond to infant's cues of distress (head moving away from the nipple, head moving back from the nipple, arms extending outward, color change, noisy respirations, coughing, choking, double swallowing, apnea) and cues of fatigue (infant body tone decreasing, milk splashing out from infant's mouth, prolonged sucking pauses) with nipple removal.
-

Table 2

Dynamic-Early Feeding Skills Regulation Categories with Code Descriptions

Categories	Description
Behavioral Organization	
Disorganized behaviorally	Behavioral disorganization is defined as observable indicators that the infant is actively trying to pull away from the nipple, extending fingers or arms, pushing nipple away, eyebrow raise or eye lid flutter, furrowed brow.
Organized behaviorally	If the infant has no indicators of disorganized behavior they are coded as being behaviorally organized.
Fluid Management	
Disorganized swallowing	Swallowing disorganization is defined as signs that the infant is not managing fluid: drooling; hard swallows; fluid remaining in pharynx or nasopharynx that is audible during respiration; multiple swallowing.
Quiet, organized swallows	If the infant has no indicators of disorganized swallowing they are coded as having quiet, organized swallows.
Work of Breathing	
Dysregulated respiration	Respiratory dysregulation is defined as signs that the infant has increased work of breathing (use of accessory muscles –visible on the videotape as head bobbing, pulling head back to take a deeper inspiration); restricted airflow audible during respiration as stridor; prolonging the exhale – audible by grunting during exhalation; color change; nasal flaring.
Respiratory regulation	If the infant has no indicators of dysregulated breathing they are coded as having respiratory regulation.

Table 3

Infant Characteristics (n = 20)

	<i>M</i>	<i>SD</i>	Range
Birthweight (grams)	970	271	557–1443
Gestational Age (weeks)	28.1	2.6	24.6–32.3
Apgar Score at 1 Minute	5.9	2.2	0–8
Apgar Score at 5 Minutes	7.3	1.8	1–9
Days on Ventilator	13.1	21.0	0–67
Days on CPAP	16.4	20.0	0–55
Days on Oxygen	60.3	31.3	16–120
PMA at First Oral Feeding (weeks)	34.3	1.5	31.1–36.7
Transition Time (Days to Full Oral Feeding)	18	10	9–45
Weight at Time of Study (grams)	2066	363	1570–3085
PMA at Time of Study (weeks)	36.7	2.0	33.6–40.4
Experience (# Days Oral Feeding Prior to Study)	16	11	2–39

Notes. CPAP = continuous positive airway pressure; PMA = postmenstrual age

Table 4

Fidelity of the Intervention: Comparison of CoReg Feedings with Usual Care Feedings Using Repeated Measures Modeling via Mixed Effects Models

		<i>N^a</i>	<i>M</i>	<i>SE</i>	Range	<i>t</i>	<i>df</i>
SL Position ^b	CoReg	35	96.06%	4.30	0 – 100		
	Usual Care	40	10.32%	4.11	0 – 100	17.99 ****	18
Rest Provided ^b	CoReg	35	5.83	0.54	0 – 14		
	Usual Care	40	3.53	0.51	0 – 10	3.51 ***	18
Cue Stop ^c	CoReg	35	15.42	1.35	1 – 41		
	Usual Care	40	0.74	1.28	0 – 15	9.21 ****	18
Stim Suck ^c	CoReg	35	0.89	1.98	0 – 7		
	Usual Care	40	15.70	1.87	0 – 49	-6.24 ****	18

Notes. SL = side-lying position (SL was mutually exclusive and exhaustive with semi-upright positioning; i.e., all infants were in one or the other position); Cue Stop = nipple stimulus removed to stop milk flow; Stim Suck = intraoral stimulation by nipple movement.

^aNumber of feeding observations.

^bPercentage of all bottle-in feeding periods.

^cNumber of events during the feeding periods.

p < .01,

p < .001

Fidelity of the Intervention: Comparison of CoReg Feedings with Usual Care Feedings Using Chi-Squared Tests from Generalized Estimating Equations Models

Table 5

		<i>N^a</i>	Percentage of Onsets	<i>SE</i>	χ^2	<i>df</i>
Prep	CoReg	253	88.25%	45.5%	16.85	1
	Usual Care	178	46.25%	20.9%		
Ready	CoReg	253	99.43%	88.2%	32.86	1
	Usual Care	178	51.96%	30.6%		

Notes. Prep = caregiver preparation of the infant pre-nipple placement by stroking the lips; Ready = infant readiness behavior at time of nipple placement

^aNumber of bottle-in feeding periods (defined as each bottle-in to next bottle-out; average four/feeding).

 $p < .001$

Table 6

Comparison of CoReg Feedings with Usual Care Feedings Using Repeated Measures Modeling via Mixed Effects Models for Oxygen Saturation and Heart Rate Variables

		<i>M</i>	<i>SE</i>	Range	<i>t</i>	<i>df</i>
PF SaO ₂	CoReg	96.75	0.45	88.33 – 99.91	-0.18	18
	Usual Care	96.83	0.43	91.29 – 100		
Mean SaO ₂	CoReg	92.75	0.62	86.69 – 97.55	1.18	17
	Usual Care	92.02	0.59	83.27 – 97.37		
Min SaO ₂	CoReg	80.95	1.42	66.87 – 92.00	1.80*	17
	Usual Care	78.57	1.37	59.22 – 88.58		
% SaO ₂ <85%	CoReg	4%	2%	0 – 27%	-2.50**	17
	Usual Care	10%	2%	0 – 53%		
PF HR	CoReg	164.88	2.45	141.40 – 190.90	0.83	16
	Usual Care	162.96	2.40	137.11 – 189.07		
Mean HR	CoReg	165.54	2.46	142.46 – 180.26	2.27**	16
	Usual Care	162.68	2.43	140.05 – 183.93		
Min HR	CoReg	130.75	5.30	78.75 – 169.15	3.68***	16
	Usual Care	114.23	5.16	69.96 – 162.82		
Max HR	CoReg	180.38	2.10	169.51 – 196.75	-0.55	16
	Usual Care	181.11	2.07	160.34 – 203.44		

Notes. PF = prefeeding; SaO₂ = oxygen saturation; HR = heart rate

* $p < .10$,

** $p < .05$,

*** $p < .01$

Table 7

Effect of Intervention on Length of Time to Feed and Nutritional Intake

		<i>n</i>	<i>M</i>	<i>SE</i>	<i>t</i>	<i>df</i>
Length of Feeding [#]	CoReg	35	976.8	91.32	1.28	17
	Usual Care	40	863.5	86.97		
Length of Suckling [#]	CoReg	35	523.0	41.83	-0.88	17
	Usual Care	40	561.6	39.56		
Caloric Intake (mL)	CoReg	35	34.5	2.94	-2.47 ^{***}	17
	Usual Care	40	38.9	2.88		
Percent Intake	CoReg	35	88%	5%	-0.60	17
	Usual Care	40	90%	4%		

Notes.

[#]Unit is seconds. Percent Intake = percent of prescribed intake ingested^{***}*p* < .05