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Effect of maternal behavior on regulation during feeding in healthy infants and infants with transposition

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Abstract

Objective—To compare physiologic regulation and the effect of maternal sensitive caregiving during feeding on physiologic regulation in healthy infants and in infants with transposition of the great arteries (TGA).

Design—Descriptive, two group, repeated measures.

Setting—Three children's hospitals in the Midwest.

Participants—A convenience sample of 15 infants with TGA matched with 16 healthy infants.

Methods—Measures of physiologic regulation before, during, and after feeding and quality of maternal affect and behavior during feeding were collected post-operatively at two weeks and two months of age.

Results—At two weeks, infants with TGA demonstrated impaired physiologic regulation with feedings when compared with healthy infants. Healthy infants of more sensitive mothers were more likely to demonstrate a physiologically adaptive response during feeding. Maternal effect on physiologic regulation was not observed in infants with TGA. No differences between groups were found at two months.

Conclusions—For infants with TGA, effects of surgical recovery and limited contact with their mothers relative to healthy infants may have outweighed the supportive effect of maternal sensitivity during feeding in the early weeks of life. Further research is needed to identify ways of enhancing the regulatory effect of maternal behavior on infants with heart defects.

Keywords

congenital heart defects; infant feeding; physiologic regulation; maternal-infant interaction

Callouts

1. Monitoring parasympathetic function is a way of assessing an individual's capacity for regulating physiologic processes and responding to stress or challenge.
2. In healthy infants, mothers' attunement, support, and warmth during feeding enhances infants' adaptive physiologic response to the feeding challenge in the early weeks of life.
3. Nurses can facilitate infants' adaptive response to feeding by assisting mothers in developing strategies for structuring supportive environments, responding to cues, and communicating consistent messages.

Feeding is reported by mothers as one of the most difficult aspects of caring for infants with complex congenital heart defects (CCHD; Imms, 2000), i.e. heart defects requiring corrective or palliative surgery within the first days or weeks of life. Feeding is a physiologic process

largely controlled by the autonomic nervous system (ANS). The ability to regulate autonomically controlled physiologic processes (physiologic regulation) is impaired in infants with CCHD (Limperopoulos et al., 2000). Higher quality interactions between mothers and infants are associated with improved physiologic regulation (Hofer, 1994; Sander, 1975), and feeding is the primary setting for mothers' interaction with their very young infants (Stern, 1995). Interactions between infants with CCHD and their mothers have been found to be qualitatively different than interactions between healthy infants and their mothers (Gardner, Freeman, Black, & Angelini, 1996; Lobo, 1992). The purpose of this study was to compare the effect of maternal behavior during feeding on physiologic regulation in healthy infants and in infants with transposition of the great arteries (TGA), one of the most common CCHDs (Centers for Disease Control and Prevention [CDC], 2006).

Theoretical Framework

Schore's theory of the development of self-regulation in infants and young children posits that the development of patterns of response of the sympathetic and parasympathetic divisions of the ANS is directly influenced by the mother's interactions with her infant (1996). Infants of mothers responding sensitively to their infants' cues develop pathways in the brain resulting in coordinated interactions between the sympathetic and parasympathetic nervous systems. These precise interactions are primarily responsible for physiologic regulation in maintaining homeostasis and in responding to stress or challenge. Infants of mothers not responding in an attuned way develop pathways in the brain resulting in a predominance of either parasympathetic or sympathetic function. These suboptimal patterns of ANS response compromise infants' capacities for maintaining homeostasis and responding to stress or challenge (Doussard-Roosevelt, McClenny, & Porges, 2001). The proposition of this study was that if the mother was attuned to the infant's needs during feeding, her effectiveness in responding to those needs would enhance the infant's ability to regulate the physiologic challenge of feeding.

Physiologic Regulation

Feeding is a challenge to physiologic regulation. Although the outcome of feeding, digestion of nutrients, is a parasympathetic activity, ingestion of food requires coordination of physiologic processes, including those involved in sucking, swallowing, and breathing, and is a stress to the homeostatic state (Doussard-Roosevelt & Porges, 1999). With the challenge of feeding, parasympathetic nervous system stimulation is reduced, allowing sympathetic effects to predominate to increase the metabolic resources needed to successfully coordinate these processes. When the ingestion of food is complete, parasympathetic activity again increases and sympathetic effects are reduced resulting in a recovery of conditions supportive of regaining homeostasis (Porges, 1996). Thus, monitoring parasympathetic function is a way of assessing an individual's capacity for regulating physiologic processes and responding to stress or challenge (Porges, 1992). (*Callout 1*)

Function of the ANS can be monitored by measuring heart rate variability (HRV; De Jong & Randall, 2005; Ohuchi, et al., 2003; Verklan, 2002). HRV is the term used to describe the minute changes in the intervals between sequential heart beats. These changes in beat-to-beat intervals reflect precise and constant interaction between effects of parasympathetic and sympathetic divisions of the ANS. In general, high levels of variability in heart rate reflect a healthy, responsive ANS able to closely regulate physiologic function; low levels of variability reflect unresponsive, less flexible functioning of the ANS, with resultant poor physiologic regulation (Pumprla, Howorka, Groves, Chester, & Nolan, 2002). Analysis of the rhythms and frequency of beat-to-beat changes is conducted based on electrocardiographic (ECG) recordings and provides a noninvasive measure of autonomic control of the heart (Task Force of the European Society of Cardiology and the North American Society of Pacing and

Electrophysiology, 1996). Diverse processes influence heart rate and operate at different frequencies that can be identified and quantified (Pumprla et al.). High frequency heart rate variability (HF HRV) occurs within the frequency band of respiration and is of primary interest in physiologic regulation because it exclusively reflects parasympathetic activity (Pumprla et al.).

Few studies have examined physiologic regulation in healthy infants and only one study looked at response to the challenge of feeding (Lappi et al., 2007). In this study, HF HRV at birth and at 6, 12, and 24 weeks of age was significantly lower during feeding when compared with pre-feeding and post-feeding levels. These reductions in HF HRV during feeding reflect the adaptive withdrawal of parasympathetic activity during feeding. The effect of feeding on physiologic regulation in infants with heart defects has only been reported in one small sample of 10 one-month-old infants with a variety of CCHDs (Winters et al., 2006). HF HRV was found to be relatively consistent across phases of feeding, i.e. reductions during feeding were not observed.

Physiologic Regulation and Maternal Behavior

Maternal behavior in interaction with her infant has a significant impact on infant physiologic regulation (Hofer, 1994; Sander, 1975). In animal studies, infant rats separated from their mothers experienced significant changes in heart rate, thermoregulation, and arousal, reflecting loss of autonomic, neuroendocrine, behavioral, and electrophysiological regulation (Hofer). In a classic study of healthy infants, the effect of a consistent, responsive caregiver on early physiologic regulation was examined in newborn infants awaiting adoption (Sander). Infants with one consistent caregiver who provided feedings based on infant cues exhibited less feeding distress (gagging, vomiting, spitting) when compared with infants who experienced multiple caregivers and rigidly scheduled feedings.

Although no studies were found in which the effect of mother's behavior during feeding on physiologic regulation in healthy term infants was examined, premature infants of mothers who adjusted their behavior during feeding in response to infant cues demonstrated less bradycardia and more stable oxygenation (Thoyre & Brown, 2004). Additionally, supporting premature infants during feeding by initiating feedings based on readiness cues and by offering non-nutritive sucking before feeding assisted infants in attaining and maintaining arousal and improved HF HRV during feeding (McCain, Fuller, & Gartside, 2005).

Interactions of Mothers and Infants with CCHD

Significant differences in the quality of interactions between mothers and infants with CCHD have been found when compared with interactions between mothers and healthy infants. During feeding, mothers of infants with CCHD demonstrated less smiling, touching, and eye contact, and infants demonstrated more distress than mothers and healthy infants (Lobo, 1992; Lobo & Michel, 1995). In another study, 20 mothers and their infants hospitalized with CCHD were found to have significantly less positive affect and engagement in their interactions than non-cardiac mother-infant pairs at two time points, two days before and six months following surgery (Gardner et al., 1996). The effects of the role or specific qualities of maternal affect and behavior on physiologic regulation during feeding have not been examined.

The specific objectives of this study were (a) to describe physiologic regulation during feeding in infants with TGA 7 to 14 days after surgical correction and six weeks later and compare this with physiologic regulation during feeding in healthy infants of the same age, and (b) to examine the effect of mother's behavior during feeding on physiologic regulation in healthy infants and in infants with surgically corrected TGA. Theorized relationships among infant

health condition, maternal feeding behavior, and time on infant response to feeding are illustrated in Figure 1.

Methods

This exploratory study was part of a larger study investigating physiologic and arousal regulation in a sample of healthy infants and infants with TGA. Sample size was based on the number of eligible infants with TGA recruited from three children's hospitals over a 15 month enrollment period and was expected to be small given the incidence of TGA at 4.8 per 10,000 live births (CDC, 2006). Additionally, given the lack of study both on HRV and on the potential influence mother's feeding behavior may have on HRV in these infants, there was little basis for estimating an effect size necessary for a power analysis. This study has enabled identification of an interpretable effect size that can be applied in the design of later studies.

Sample

The sample for this longitudinal, descriptive study design consisted of 15 infants with TGA recruited within the first week of life from three major metropolitan children's hospitals in the Midwest and 16 healthy infants recruited from one large birth center affiliated with one of the children's hospitals. Healthy infants were matched case by case with TGA infants on three variables that could potentially affect the measure of HF HRV: gender (Silvetti, Drago, & Ragonese, 2001), age (Massin et al., 2001), and feeding type (breast or bottle; Marino, O'Brien, & LoRe, 1995). One additional healthy infant was included because one mother of an infant matched for breastfeeding stopped breastfeeding before data collection was complete. Because matching was done to obtain closely equivalent groups and not for statistical analysis of matched pairs, data for this mother and infant were included in analysis. Inclusion criteria included: (a) full-term infants either healthy or diagnosed with TGA prenatally or at birth with no co-morbidities and (b) English-speaking mothers at least 18 years of age or who were legally emancipated, and who would be the primary caregiver.

Measures

Physiologic regulation was measured by HRV using continuous ECG recordings collected with a three-channel ambulatory Holter recorder (Marquette Electronics, Inc., Milwaukee, WI). Data were digitized at 128 Hz using a MARS 5000® Ambulatory ECG Analysis and Editing System (General Electric, Inc.). Each ECG complex was identified and characterized with regard to morphology by the computer software. This preliminary analysis was then overread and edited to assure that proper identification had occurred. Artifact was eliminated. Final calculations were based solely on normal sinoatrial node initiated complexes. HRV was calculated using frequency domain measures, determined by power spectral analysis. Using fast Fourier transformation (FFT) of continuous ECG data segments, high frequency power (HF HRV) was quantified in five minute epochs. The value for each epoch was the average interval between heart beats for that epoch expressed in milliseconds, squared. For analysis, these epochs were averaged over the duration of each of the three feeding phases (pre-feeding, during-feeding, and post-feeding). The high frequency band width was calculated separately for each infant based on average respiratory rate during data collection. Reliability of FFT has been tested by applying the FFT algorithm to standard shapes with known transforms (Marquette Electronics, Inc., 1992). Because frequency domain measures have skewed distributions (Kleiger et al., 2005), the data were log transformed to normalize the distribution and are thus reported as the natural log of milliseconds, squared [$\ln(\text{ms}^2)$]. Median values were used for analysis to obtain a closer measure of central tendency (Tabachnik & Fidell, 2001).

Maternal Feeding Behavior was measured using the Parent-Child Early Relational Assessment (ERA), a 65 item observational rating scale designed to assess the quality of affect and behavior

in parent-child interactions (Clark, 1985; Clark, 1999; Clark, Tluczek, & Gallagher, 2004). Ratings were based on observations from the first five-minute section of videotaped feedings. One subscale was used, maternal support, attunement, and warmth (MSAW), derived theoretically for this study using 10 parent items especially pertinent to the feeding task: sensitivity and responsivity, flexibility, structuring and mediating the environment, lack of intrusiveness, consistency and predictability, positive affect, lack of depression or withdrawn mood, visual contact, warm and kind tone of voice, and amount of verbalization. Each item was rated on the basis of duration, intensity, and frequency of the behavior and/or affect observed. Items are scored on a scale of 1 to 5 with 1 = negative affect or behavior and 5 = regulated, adaptive behavior. Responses can be grouped clinically into three categories: 4 or 5 = area of strength, 3 = some concern, and 1 or 2 = concern. Cronbach's alpha coefficients of internal reliability were calculated based on the exact five response scale and were .89 at Time 1 and .86 at Time 2. A trained coder who was blind to the study aims and to the families coded 100% of the videotapes. To determine intercoder reliability, a second trained coder independently coded a random sample of 15% of the videotapes. After intercoder reliability was assessed, discrepant codings were discussed and consensus was reached. The proportion of exact agreement for the scale used in this study was .87 for the exact 5 scale response and .94 within the 3 clinical categories. Cohen's kappa was .73 for the 5 scale response and .78 within the 3 clinical categories.

Procedures

After obtaining the mother's written informed consent, a Holter recorder was attached to the infant's chest using seven neonatal electrodes. At each data collection, ECG recordings were made for 30 minutes prior to feeding, for the duration of the feeding, and for 60 minutes after the feeding was completed. The feedings were videotaped. Time 1 data collection for the TGA group took place in the hospital 7 to 14 days after the surgical correction. Time 1 data collection for the comparison group took place in the home with infant age in days consistent with matched TGA participant. For both groups, Time 2 data collection took place in the home six weeks after Time 1. The study was approved by human subjects review boards in each of the participating hospitals and academic institutions.

Data Analysis

Data were analyzed using fixed occasion, multiple condition, regression analysis (Diggle, Liang, & Zeger, 1994; Goldstein, 1986). In this model, one regression equation was constructed for each phase of feeding at each of the two time points. The dependent variables for the resulting six equations were: Time 1 Pre-Feeding HF HRV, Time 1 During-Feeding HF HRV, Time 1 Post-Feeding HF HRV, Time 2 Pre-Feeding HF HRV, Time 2 During-Feeding HF HRV and Time 2 Post-Feeding HF HRV. The measure of HF HRV from the preceding feeding phase was included as a covariate and was centered to enhance interpretability of the parameter coefficients. Three predictor variables were included in the model: infant Group (dummy coded as healthy = 0 and TGA = 1), MSAW, and the interaction term Group by MSAW. MSAW was centered around the clinically significant value of four: an MSAW score of four or above is considered a strength and a score less than four is considered an area of some concern. The Pre-Feeding equations had only one predictor, Group, because there was no measure of HF HRV preceding that phase of feeding and MSAW was measured only during feeding. MSAW was included in the Post-Feeding equations to examine whether maternal behavior during feeding had an effect after the feeding was completed.

The resulting model of six equations was run simultaneously. In this way, the relationships among the dependent variables and between the two time points could be controlled for statistically. The parameter estimates were interpreted as the expected change in the dependent variable given one unit of change in the independent variable of interest while controlling for

each of the other predictors in the equation. Given the exploratory nature of this study, alpha level for all significance tests was set at .05. Coefficients and contrasts were tested using approximate Wald statistics (Goldstein, 1995). Whenever possible, exact probabilities were used for analyses, reducing the risk of overestimating probabilities in this small data set (StatXact 7 PROCS, 2005). Bootstrapping, a statistical technique in which the parameter estimates and the standard errors are generated over a large number of replications of the data, was used to reduce standard error, thus providing estimates likely more accurate relative to population values ((Tabachnik & Fidell, 2001). Components of the aims were addressed using Mann-Whitney or Wilcoxon Signed Rank tests.

Results

The samples of mothers of infants with TGA and mothers of healthy infants were similar (see Table 1). The majority of mothers in both groups were non-Hispanic, non-Latino Whites in their late 20s with some college education. The infants had surgery an average (SD) of 6.80 (2.98) days of age and their average (SD) length of stay was 20.13 (6.05) days.

Assumptions for the regression model were met. Missing data were present for HF HRV for two healthy infants at Time 1 at the Pre-Feeding phase and one infant with TGA at Time 2 at the During-Feeding phase due to equipment malfunction. One infant received full nasogastric (NG) feedings at Time 1. This infant was removed from analysis for During-Feeding and Post-Feeding HF HRV measures at this time point. Five infants at Time 1 and one infant at Time 2 had partial NG feedings. For these six cases, the NG feeding was included in the Post-Feeding phase measure because the passive receipt of nutrients is physiologically closer to post-feeding than the active ingestion of nutrients that occurs during feeding.

Mann-Whitney tests were used to compare study variables. Maternal feeding behavior measures, MSAW, were significantly higher in mothers of TGA infants when compared with mothers of healthy infants at Time 1 ($U = 65.50, p = .030$), but not at Time 2 ($U = 87.50, p = .202$). Healthy infants demonstrated reductions in During-Feeding HF HRV at both time points while infants with TGA demonstrated similar HF HRV values across the three feeding phases at Time 1 and reductions in During-Feeding HF HRV at Time 2 (see Figure 2). Wilcoxon Signed Rank tests with exact probabilities were used to examine changes over time (see Table 2). Healthy infants did not demonstrate significant changes between the two time points in any of the feeding phases. However, infants with TGA significantly increased Pre-Feeding HF HRV and Post-Feeding HF HRV between Time 1 and Time 2 (Pre-Feeding: $T = -2.224, p = .022$; Post-Feeding: $T = 2.272, p = .022$). During-Feeding HF HRV in infants with TGA did not change over time.

Results for each of the model predictor variables are given on Table 3. At Time 1, infants with TGA were significantly more likely to have lower Pre-Feeding (Wald $Z = 2.543, p = .011$) and Post-Feeding (Wald $Z = 2.647, p = .008$) and higher During-Feeding (Wald $Z = 2.564, p = .010$) HF HRV. No significant group effects were found at Time 2.

MSAW had a significantly negative effect at Time 1 During-Feeding (Wald $Z = -2.068, p = .039$), indicating that infants of mothers who demonstrated more attunement, support, and warmth had an adaptively lower During-Feeding HF HRV. However, a significant interaction effect was also found, signifying that the supportive effect of maternal behavior on infant physiologic regulation occurred only in healthy infants (Wald $Z = 1.976, p = .048$). These effects were not present at Time 2.

Discussion

In this study, regression model parameter estimates demonstrated that group (healthy or TGA) was a significant predictor of physiologic regulation, as measured by HF HRV, across all three phases of feeding in the early weeks of life. Healthy infants were more likely to have higher Pre-Feeding, lower During-Feeding, and higher Post-Feeding HF HRV when compared with infants with TGA. This pattern of response to the challenge of feeding demonstrated high baseline parasympathetic function supportive of restoration and growth, an adaptive reduction of parasympathetic function during feeding supportive of the enhanced metabolic requirements involved in the process of ingesting food, and a return to high levels of parasympathetic function post-feeding supportive of digestion. This finding is consistent with previous work with healthy infants (Lappi et al., 2007).

In contrast, infants with TGA were more likely to have lower levels of HF HRV as a baseline state before feedings, little change during feeding, and lower levels after feeding when compared with healthy infants. This pattern of HF HRV suggests that, early after surgical correction, infants with TGA experienced persistent parasympathetic withdrawal. When the parasympathetic nervous system is persistently functioning at relatively low levels, the body is limited in its ability to support the homeostatic conditions necessary for restoring and conserving energy, digesting and utilizing nutrients, and supporting growth, as well as to respond to stress or challenge (Porges, 1996).

Importantly, regression model parameter estimates demonstrated that healthy infants of mothers exhibiting more attunement, support, and warmth during feeding experienced reductions in HF HRV during feeding. (*Callout 2*) This supportive effect of maternal feeding behavior on the infant's adaptive response to feeding is consistent with Schore's theory of the relationship between maternal sensitive caregiving and ANS function (1996). This theory would propose that the mother's ability to respond sensitively during feeding (e.g., structuring and mediating the environment appropriately, demonstrating less rigidity and more flexibility, and refraining from intrusive behavior) would support the young infant in successfully organizing the physiologic processes involved in sucking, swallowing, and breathing.

Maternal feeding behavior did not affect physiologic regulation infants with TGA. Several possible explanations for this finding may be considered. First, infants with TGA at this point in time were hospitalized and recovering from surgery. The physical stress of surgical recovery has been reflected in reductions in parasympathetic function and increases in sympathetic function in adults (Ushiyama et al., 2008). Although the effect of surgery on ANS function has not been examined in infants, effects similar to those in adults are likely. In contrast with the consistent maternal caregiving experienced by healthy infants in the home, infants with TGA experienced comparatively limited maternal contact as well as multiple caregivers at this point of time of recovery in the hospital. Both of these factors are associated with impaired infant physiologic regulation (Hofer, 1994; Sanders, 1975). It is possible that, for infants with TGA, effects of surgical recovery, multiple caregivers, and more limited contact with their mothers relative to healthy infants may have outweighed the supportive effect of maternal sensitivity during feeding in the early weeks of life.

Second, an assumption was made in this study that an adaptive response for infants with TGA would look like the response healthy infants made. However, a physiologically adaptive response to the challenge of feeding in infants with TGA as compared to healthy infants has not been defined. Even before confronting the challenge of feeding, infants with TGA in this sample demonstrated parasympathetic withdrawal as a baseline steady state. Perhaps supportive, attuned, and warm caregiving from the mother assisted the infant in maintaining relatively constant levels of HF HRV across phases of feeding. It is possible that consistency

in modulation of parasympathetic and sympathetic function is important to these infants physiologically, i.e. maintaining steady levels may prevent greater sympathetic activation in response to challenge which could potentially overwhelm the infant's capacity to respond. This study provided a first step toward developing a definition of a physiologically adaptive response to feeding by describing what occurred in this population. Further research in this area will be essential to more thoroughly describe these mechanisms.

Finally, it is also possible that these infants did have a sympathetic response to feeding, but the type of measure analyzed did not identify that response. In this study, HF HRV was used as a measure of parasympathetic function. Increases and reductions in parasympathetic function have been proposed as a measure of an individual's capacity for responding to stress (Porges, 1992). Perhaps examining parasympathetic function alone does not provide sufficient information for assessing response to stress when prolonged physiological challenges, such as recovery from surgery, are experienced. It is possible that even though HF HRV was relatively consistent across feeding phases, the influence of sympathetic function may have changed. At least two studies in the adult literature have shown that in response to a challenge, HF HRV may remain unchanged while sympathetic activity, as measured by changes in low frequency HRV, is increased (Appelhans & Luecken, 2008; Terkelsen et al., 2005). Expanding the analysis in future studies to additional frequencies of HRV power may provide clarification of relationships between challenge and physiologic regulation in this population of infants.

One unexpected finding was that, compared with mothers of healthy infants, mothers of infants with TGA had significantly higher scores in maternal support, attunement, and warmth at the early post-operative observation. These findings are not consistent with the only other studies found in which interactions between infants with CCHDs and their mothers were examined (Gardner et al., 1996; Lobo, 1992). In both of these studies, mothers of infants with cardiac defects demonstrated less sensitive caregiving when compared with mothers of healthy infants. These studies differed from the current study in several ways.

First, both of the previous studies included infants with a variety of CCHDs, whereas the current study exclusively examined infants with TGA, whose prognosis after corrective surgery is excellent (Dibardino, Allison, Vaughn, McKenzie, & Fraser, 2004). A mother's behavior toward her infant may vary depending on how she perceives the infant's prospects of survival. Second, in the previous studies, some of the infants had not yet undergone surgery at the time of the study. The way in which a mother interacts with her infant may vary depending on the imminence or history of life-saving, yet life-threatening, surgery. Third, these studies differed in the type of measures used which limits comparability.

Finally, it is possible that previous studies, such as Gardner et al. (1996), Lobo (1992), and others in which relationships between mothers and infants with other chronic health conditions were examined, have informed nursing practice. In the last decade, more focus has been given to providing developmentally appropriate, supportive nursing care which has as a defining characteristic the need to assist mothers in identifying and responding to infant cues (Als et al., 2004). It is quite possible that the mothers in the current study benefitted from improvements in nursing practice over the past decade.

Significant differences between groups on physiologic regulation during feeding as well as on the effects of maternal feeding behavior on physiologic regulation were not identified when the infants were two months of age. It is possible that by two months of age, the majority of these full-term infants had mastered the skills required for feeding and was able to successfully self-regulate the challenge. Another possible explanation is that mothers, on the whole, may have been more equivalent in their ability to support their infants during feeding. Future studies

with a larger sample and more heterogeneity among mothers may assist in clarifying this question.

Limitations of the study

The homogeneous sample created by examining infants with a single type of cardiac defect was important in describing mechanisms and relationships regarding physiologic regulation. However, this strategy reduced the eligible population and resulted in a small sample. The data analysis methods used allow for confidence in the significant findings (Hart & Clark, 1999), but a larger sample size may have identified more significant differences between groups and over time. The setting in which this study was conducted was both a strength and a limitation. Collecting observational data in naturalistic settings allows the researcher to more accurately assess what is happening in realistic settings and situations. However, without the protected environment of a laboratory, it was difficult to control potential external influences on the measurements, particularly in the hospital setting.

Nursing Implications

(Callout 3) Infants with TGA experience sustained parasympathetic withdrawal early after corrective surgery which may impact their ability to respond adaptively to the challenge of feeding. Findings from this study suggest that infants may respond to challenges more adaptively when supported by sensitive maternal caregiving behavior. Nurses can facilitate this support by assisting mothers in developing strategies for structuring a supportive environment, in recognizing and responding to subtle infant cues, and in communicating consistent and congruent messages through affect and behavior. Additionally, nurses may assist in enhancing infants' parasympathetic function through encouraging frequent and prolonged direct physical contact between mothers and infants and using innovative scheduling to provide consistent caregivers for these and other hospitalized infants.

Conclusion

Findings from this study demonstrated that physiologic regulation differed between infants with TGA and healthy infants before, during, and after feeding in the early weeks of life. In addition, maternal behavior during feeding was supportive of an adaptive response to feeding in healthy infants, but was not seen in infants with TGA. Although these differences in physiologic regulation had largely disappeared by two months of age, it is possible that the small sample may have affected the ability to find significant differences. Further research is essential to more thoroughly describe mechanisms involved in the infant's physiologic response to feeding and its development over time. This may include examining maternal and infant characteristics that could affect interactions, conducting follow-up studies over longer periods of time to examine change or stability in physiologic regulation, and identifying ways of enhancing the regulatory effect of maternal sensitive caregiving on infants with CCHDs.

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Figure 1.

Theorized relationships among study variables at three phases of feeding. Boxes indicate variables examined as predictors of HF HRV. Solid black lines indicate the continuum of the phases of feeding. Dashed lines indicate relationships examined in this study.

HF HRV at Each Feeding Phase by Group

Figure 2. HF HRV (high frequency heart rate variability) at each feeding phase and each time point by Group.

Table 1

Maternal and Infant Demographic Variables by Group

Variable	TGA n = 15				Healthy n = 16			
	n	%	mean	SD	n	%	mean	SD
Infant gender								
Male	9	60.0			10	62.5		
Female	6	40.0			6	37.5		
Feeding type								
Breast	5	33.3			5	31.2		
Bottle	10	66.7			11	68.8		
Infant age at data collection (days)								
Time 1			17.13	3.94			17.44	3.98
Time 2			59.07	4.40			59.31	4.27
Maternal age (years)			28.67	4.97			29.69	5.79
Married/partnered mothers	15	100			9	56.3		
Maternal education								
Less than bachelor's degree	8	53.4			13	81.3		
Bachelor's degree or higher	7	46.6			3	18.7		
Race/ethnicity								
Black or African American	1	6.7			5	31.2		
Non-Hispanic, White	14	93.3			10	62.6		
Hispanic, White	0	0			1	6.2		

Table 2

Change in HF HRV between Time 1 and Time 2 by Group

Feeding Phase	TGA		Healthy	
	Time 1	Time 2	Time 1	Time 2
	M(SD)	M(SD)	M(SD)	p
Pre-Feeding HF HRV	2.84 (.91)	3.65 (.94)	3.51 (.59)	3.70 (.65)
Dur-Feeding HF HRV	2.76 (1.04)	3.26 (.88)	2.99 (1.05)	3.39 (.73)
Post-Feeding HF HRV	2.80 (.97)	3.45 (.81)	3.55 (.78)	3.64 (.47)

Note. Time points compared using Wilcoxon Signed Ranks tests.

Table 3

Parameter Estimates Predicting HF HRV by Feeding Phase^a

	Intercept	Pre-Phase HRV	Group	MSAW	Group by MSAW
T1PreHRV	3.552 (.205)*		-.735 (.289)*		
T1DurHRV	2.281 (.312)*	.996 (.200)*	.882 (.344)*	-1.028 (.497)*	.974 (.493)*
T1PostHRV	3.478 (.190)*	.514 (.094)*	-.675 (.255)*	.006 (.022)	.003 (.023)
T2PreHRV	3.731 (.202)*		-.100 (1.135)		
T2DurHRV	3.265 (.150)*	.678 (.121)*	-.018 (.093)	-.297 (.228)	.311 (.322)
T2PostHRV	3.667 (.147)*	.468 (.112)*	-.171 (.253)	.112 (.261)	.031 (.090)

Note. HF HRV = high frequency heart rate variability, T1PreHF = Time 1 Pre-Feeding HF HRV, T1DurHF = Time 1 During-Feeding HF HRV, T1PostHF = Time 1 Post-Feeding HF HRV, T2PreHF = Time 2 Pre-Feeding HF HRV, T2DurHF = Time 2 During-Feeding HF HRV, T2PostHF = Time 2 Post-Feeding HF HRV, MSAW = Maternal support, attunement, warmth.

^a All values are bootstrapped estimates.

* $p < .05$