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Autonomic nervous system function, child behavior, and maternal sensitivity in three-year-old children with surgically corrected transposition

Tondi M. Harrison, PhD, RN, CPNP [a,b,*]

[a] Center for Cardiovascular & Pulmonary Research, The Research Institute at Nationwide Children's Hospital, USA
[b] Department of Pediatrics, College of Medicine, The Ohio State University, Columbus, OH, USA

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ABSTRACT

Objectives: Explore relationships among autonomic nervous system (ANS) function, child behavior, and maternal sensitivity in three-year-old children with surgically corrected transposition of the great arteries (TGA) and in children healthy at birth.
Background: Children surviving complex congenital heart defects are at risk for behavior problems. ANS function is associated with behavior and with maternal sensitivity.
Method: Child ANS function (heart rate variability) and maternal sensitivity (Parent–Child Early Relational Assessment) were measured during a challenging task. Mother completed the Child Behavior Checklist. Data were analyzed descriptively and graphically.
Results: Children with TGA had less responsive autonomic function and more behavior problems than healthy children. Autonomic function improved with more maternal sensitivity.
Conclusion: Alterations in ANS function may continue years after surgical correction in children with TGA, potentially impacting behavioral regulation. Maternal sensitivity may be associated with ANS function in this population. Continued research on relationships among ANS function, child behavior, and maternal sensitivity is warranted.

Children surviving complex congenital heart defects (CCHD) are at risk for problems regulating social and emotional behavior, including inattention, impulsivity, anxiety, depression, and aggression.[1–3] These children have undergone extensive surgical interventions during infancy. Researchers to date have focused on the infant's pre-operative condition[4] and perioperative management[5] as likely causal factors for these adverse behavioral outcomes during childhood. However, other factors may be important including development of abnormal autonomic nervous system (ANS) function.[6–8]

Presence of CCHD is associated with altered ANS function.[6–10] When compared with healthy controls, infants and children with a variety of CCHDs demonstrate lower heart rate variability (an index of autonomic function) during states of homeostasis[6,11,12] as well as impaired autonomic response to stress or challenge, e.g., infant feeding.[8] Altered ANS function early in life may become permanent[13] and is associated with social, emotional, and behavioral problems in healthy children[13,14] and in children born prematurely.[15] Relationships between altered ANS function and behavior in children with CCHD have not been examined.

The quality of a mother's caregiving affects ANS function, i.e., infants and children of more supportive mothers exhibit better autonomic regulation at rest as well as in response to challenge.[13,16] Quality of interactions between infants with CCHD and their mothers have been infrequently examined and results have been mixed.[17–19] No studies of maternal interactions with children with CCHD have been done. The aims of this study were to descriptively and graphically compare (1) ANS function, (2) child social and emotional behavior, and (3) maternal sensitivity in three-year-old children with surgically corrected TGA and in children healthy at birth.

Methods

A descriptive, two group design was used for this exploratory follow-up study.

Sample

The sample used in this study was recruited from infants and mothers who participated in a longitudinal study of relationships

* Center for Cardiovascular & Pulmonary Research, The Research Institute at Nationwide Children's Hospital, 700 Children's Drive, JW4989, Columbus, OH 43205, USA. Tel.: +1 614 355 3623.
E-mail address: Tondi.Harrison@nationwidechildrens.org.

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between maternal caregiving and infant ANS function in early infancy.[8,19,20] Each mother participating in the infant study gave written consent to be contacted for future research. The infant study included 15 infants with TGA, six of whom had an associated ventricular septal defect which classified them as having a more severe defect, and 16 infants healthy at birth. The TGA infants were recruited from three large children's hospitals in the Midwest; healthy infants were recruited from a birth center affiliated with one of the children's hospitals. Infants with TGA had surgery at a mean (SD) of 6.8 (2.98) days of age with a range of 2–11 days. Mean (SD) cardiopulmonary bypass time was 175.93 (48.80) minutes, cross clamp time 102.27 (38.44) minutes, days ventilated 4.53 (1.20), and length of hospital stay 20.13 (6.05) days.

Mothers participating in the infant study were contacted by mail within one month of their child's third birthday. The mailing included a letter that summarized the study and a copy of the informed consent document. The letter was followed within a week by a telephone call from the author to further discuss the study, respond to questions, and invite participation. When the mother verbally agreed to participate, the data collection visit in the family's home was scheduled.

Measures

Autonomic nervous system function

ANS function was measured using heart rate variability, i.e., the change in intervals between heart beats that reflects a constant and precise interaction between sympathetic and parasympathetic activity.[21] High frequency heart rate variability (HF HRV), reflecting activity of the vagus nerve, is an accepted measure of parasympathetic activity,[21] is commonly used to assess autonomic response to stress or challenge,[14,16] and is closely associated with the ability to regulate social and emotional behavior.[14,16]

Heart rate variability data were collected with continuous electrocardiograph (ECG) recordings from a 3-channel ambulatory Holter recorder (General Electric, Inc.) during a structured task designed to elicit emotional and behavioral regulation. Consistent with a developmental science approach to research, constructs are measured using tasks appropriate to the age under investigation.[22] For the infant study, feeding was used as the challenge task.[8,19,20] Beyond infancy, feeding no longer elicits predictable changes in ANS function.[23] Therefore, an age-appropriate standardized procedure requiring regulation of affect and behavior,[24] similar to tasks used in previous research,[16,25] was used for this follow-up study to elicit parasympathetic activity. With challenge, reductions in HF HRV are expected, reflecting parasympathetic withdrawal; when the challenge is complete, increases in HF HRV are expected, reflecting increases in parasympathetic activity.[8,26]

Data were digitized at 128 Hz using an 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 using a pattern-matching method to detect R waves. This preliminary analysis was then overread and edited by the author to assure that proper identification of QRS complexes had occurred. Artifact and ectopic beats were eliminated. Final calculations were based solely on normal sinoatrial node initiated complexes. Heart rate variability was calculated using frequency domain measures determined by fast Fourier transformation with Hanning window weighting to produce an interval function defined continuously in time and resampled at equal spacing to produce 1024 samples of the normal-to-normal beat interval function for every 300 s. Power in the high frequency domain was quantified at .15–1.0 Hz. Values expressed in ln (ms^2) were calculated for each of three 5 min task phases: 5 min immediately preceding the structured task, the first 5 min of the task, and 5 min immediately following the task. Change scores were computed to measure *autonomic reactivity* by subtracting pre-task HF HRV (baseline) from during-task HF HRV (challenge). Negative values indicated decreases in HF HRV, the expected response to this type of challenging task. *Autonomic recovery* was measured using change scores computed by subtracting during-task HF HRV from post-task HF HRV. Positive values indicated increases in HF HRV post-task, the expected response to recovery from the task.

Child social and emotional behavior

Behavioral and emotional competencies were measured using the Child Behavior Checklist $1^1/_2$–5 (CBCL), a parent-completed, 110 item tool with a 3 point scale.[27] Higher scores indicate more behavioral problems. Three groupings of the items were used. The Internalizing grouping measures problems occurring within the self, such as being withdrawn or depressed. Possible range of scores is 0–72 with scores at or above 18 considered clinically important. The Externalizing grouping measures problems that involve conflicts with others, such as aggressiveness and impulsivity. Possible range of scores is 0–48 with scores at or above 25 considered clinically important. The Total grouping provides a comprehensive measure of Internalizing and Externalizing as well as problems with sleep and other issues not already covered, such as fears and physical complaints. Possible range of scores is 0–200 with scores at or above 61 considered clinically important. Reliability, as well as discriminant, construct, and criterion validity have been established.[27,28]

Quality of maternal affect and behavior

The Parent–Child Early Relational Assessment (PCERA)[24,29] was used to measure maternal affect and behavior. Scores were calculated on a 5-point scale from observations of a 5-min videotaped maternal–child interaction during a structured task. Data were collected on all three parent subscales. Parental Positive Affective Involvement, Sensitivity, and Scaffolding (PAIR, 14 items) include items such as expressed positive affect, structuring and mediating the environment, and reading and responding to child cues sensitively. Parental Negative Affect and Behavior (PNAB, 6 items) includes items such as angry hostile mood, displeasure toward child, and inconsistency or unpredictability. Parental Anxiety and Intrusiveness (PAI, 6 items) include items such as anxious mood, rigidity, and quality and amount of negative physical contact. 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 1–5 with 1 = negative affect or behavior and 5 = regulated, adaptive behavior. Responses of 4 or 5 indicate areas of strength, 3 indicate some clinical concern, and 1 or 2 indicate clinical concern. Cronbach's alpha coefficient of internal reliability was calculated for this study with resultant alpha coefficients for PAIR of .92, for PNAB of .88 and for PAI of .74. A trained coder blinded to the study aims coded 100% of the videotapes. To determine intercoder reliability, a second trained coder blinded to the study aims independently coded a random sample of 25% of the videotapes at the beginning, middle, and near the end of the coding process. After intercoder reliability was assessed, discrepant codings were discussed and consensus was reached. The overall proportion of exact agreement for the parent items used in this study was .81 and Cohen's kappa was .74.

Data to describe the sample

Maternal, child, and family data were obtained and included household income, number of children in the household, and mother's education, age, parity, and marital status. Child health information included significant health issues since early infancy, including diagnosis of a chronic health condition, surgeries, and hospitalizations.