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Infants with complex congenital heart diseases show poor short-term memory in the mobile paradigm at 3 months of age

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ABSTRACT

The purpose of this study was to examine learning, short-term memory and general development including cognitive, motor, and language domains in infants with Complex Congenital Heart Defects (CCDH). Ten infants with CCHD (4 males, 6 females) and 14 infants with typical development (TD) were examined at 3 months of age. The mobile paradigm, where an infant's leg is tethered to an overhead mobile, was used to evaluate learning and short-term memory. The Bayley Scales of Infant Development 3rd edition (Bayley-III) was used to evaluate general development in cognitive, motor, and language domains. Infants with CCHD and infants with TD both showed learning with significant increase in kicking rate ($p < 0.001$) across periods of the mobile paradigm, but only infants with TD demonstrated short-term memory ($p = 0.017$) in the mobile paradigm. There were no differences on cognitive, motor, and language development between infants with CCHD and infants with TD on the Bayley-III. Early assessment is necessary to guide targeted treatment in infants with CCHD. One-time assessment may fail to detect potential cognitive impairments during early infancy in infants with CCHD. Supportive intervention programs for infants with CCHD that focuses on enhancing short-term memory are recommended.

1. Introduction

Congenital heart diseases are structural abnormalities of the heart or intrathoracic great vessels and have an incidence in the United States of approximately 9 per 1000 live births (Lloyd-Jones et al., 2009). About 25% of these defects are complex, requiring surgical intervention within the first year of life for survival (Lloyd-Jones et al., 2009). With improvements in surgical techniques and perioperative care, the survival rate of infants with complex congenital heart disease (CCHD) has increased to 82.5% (Galantowicz et al., 2008; Williams et al., 2000). With increased life expectancy, developmental impairments are now being identified (Freed et al., 2006). At school ages, children with CCHD often show poor performance in cognition, motor, and attention skills (Granberg, Rydberg, & Fisher, 2008). At preschool and toddler ages, children with transposition of great arteries (TGA) and hypoplastic left heart syndrome (HLHS) are at higher risk for motor, cognitive, and language impairments (Brosig, Mussatto, Kuhn, & Tweddell, 2007; Freed et al., 2006).

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Historically, the focus in caring for infants with CCHD has been survival. The majority of infants with CCHD are now living into adulthood and the focus has become neurodevelopmental outcomes. Infants with CCHD are more likely to have neurological impairments as a result of brain immaturity and injury before and after surgery, contributing to developmental impairments (Clouchoux et al., 2012; Licht et al., 2009; Mahle et al., 2002). Brain injuries in infants with CCHD may be a result of hypoxia/ischemia during the fetal stage or during post-natal stages because of impaired circulatory function and post-surgery sequelae (Mahle et al., 2002). In addition, infants with CCHD demonstrate impaired autonomic nervous system function at rest and in response to stress (Harrison & Brown, 2012), limiting their ability to maintain physiological stability and respond appropriately to external stimuli. Moreover, infants with CCHD may experience long hospitalizations, early invasive procedures, and home monitoring – external factors that limit normal exploratory behaviors and development.

Cognitive and motor function before 1 year of age is not tested routinely in infants with CCHD (Marino et al., 2012). Current recommendations for birth to 12 months focus on medical history review, anthropometric measurements, neurologic signs, feeding difficulties, and child–parent interactions (Marino et al., 2012). However, the information gathered from these tests may not be adequate in determining mild and moderate impairments. If cognitive and motor impairments are identified early, infants with CCHD can receive targeted intervention which could lessen the expression of disability.

To date, little is known about neurodevelopment in early infancy. Two previous studies demonstrated that infants with CCHD have poor cognitive and motor performance before 1 year of age on standardized clinical scales (Rajantie et al., 2013; Visconti et al., 2006). Only one performed the assessment before 6 months of age using the Alberta Infant Motor Scale (AIMS) that tests the motor domain only (Rajantie et al., 2013). Cognitive performance is best assessed with infants as active participants e.g. evaluating attention, learning, and memory when they are actively engaged. For example, full-term healthy infants show learning and short-term memory in the mobile paradigm where leg kicking causes conjugate mobile movement. In contrast, preterm infants, at high-risk for developmental delays and cerebral palsy, show impaired learning and do not demonstrate short-term memory in the same task (Heathcock, Bhat, Lobo, & Galloway, 2004). No investigators have studied cognitive ability in infants with CCHD in the first months of life. Therefore, the purpose of this preliminary study was to comprehensively assess performance in a cognitive task, which includes learning and short-term memory, and in general development, which includes motor, cognitive, and language domains, in 3-month-old infants with CCHD and typically developing (TD) infants. We hypothesized that infants with CCHD would show impaired learning, short-term memory, motor, cognitive, and language skills.

2. Materials and methods

2.1. Participants

Ten full-term infants with CCHD participated in this study. Inclusion criteria were: gestational age ≥36weeks and diagnosis of a CCHD requiring surgical intervention within the first month. Exclusion criteria included the diagnoses of genetic disorders or serious neurological signs that precipitated referral to neurologist. No infants from our recruitment pool with CCHD were excluded. Seventeen full-term infants were recruited from the community and reported as TD by a parent.

2.2. Measurements

Learning and short-term memory were measured using the mobile paradigm, a tool that has been used to assess infant learning and memory for more than 50 years (Rovee & Rovee, 1969), and can identify and predict impairment in preterm infants (Lobo & Galloway, 2013). In the mobile paradigm, the infant's right leg is tethered to one of two identical mobile stands with a soft cuff, and three conditions are observed by moving the mobile from one stand to another. The mobile used in this study was composed of five colorful wooden blocks with a white X and five bells, providing both visual and auditory reinforcement (Fig. 1). The first 3 min is baseline, during which infants can see the mobile but they are not able to move it with kicking. The next 9 min is acquisition. During acquisition, the infant's leg is tethered to the stand with the mobile, and thus the mobile moves in accordance with kicking movements. The nine minutes of acquisition were divided into three 3-minute blocks, named first, second and third acquisition. The final 3 min is extinction, during which the infant's leg is attached to the stand without the mobile, as in baseline (Heathcock et al., 2004). The paradigm is administered on two successive days, allowing researchers to examine if infants learn and remember a conjugate relationship.

Kicks were coded during baseline, acquisition and extinction. A kick was defined as a simultaneous flexion or extension of the knee and hip of more than 15 (Heathcock et al., 2004). Learning and memory were defined at two levels: (1) the group level by absolute kicking rate (number of tethered leg kicks), and (2) the individual level by a normalized kicking rate (tethered leg kicking rate at 1st, 2nd or 3rd acquisition or extinction/tethered leg kicking rate at baseline) (Heathcock et al., 2004; Rovee & Rovee, 1969). Learning was defined for individual infants as a Day 1 normalized kicking rate of ≥1.5 during both the third acquisition and extinction. Within each group, learning was defined as significant increase in aggregate kicking rate in third acquisition and extinction compared to Day 1 baseline (Gekoski, Fagen, & Pearlman, 1984).

Short-term memory refers to evidence that on Day 2, 24 h after the Day 1 mobile paradigm, infants remembered the cause-and-effect relationship. At the group level, short-term memory was defined as a significant increase in kicking rate