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Perinatal stroke causes abnormal trajectory and laterality in reaching during early infancy

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ABSTRACT

The developmental progression of reaching and early signs of upper extremity neglect is common concern for infants at risk for hemiparesis and cerebral palsy. We investigated the emergence of reaching and laterality in infants at risk for hemiplegic cerebral palsy. Eight infants with perinatal stroke (PS) and thirteen infants with typical development (TD) were assessed bimonthly from 2 to 7 months of age for 10 visits per infant. Reaching number and hand-toy contact duration were measured. Infants with PS demonstrated a linear trajectory of reaching behaviors with asymmetrical upper extremity performance. Infants with TD demonstrated a linear and quadratic trajectory of reaching behaviors and symmetrical upper extremity performance over the same age range. These results suggest that infants with PS have delay reaching and early signs of neglect not currently accounted for in clinical practice.

1. Introduction

Perinatal stroke (PS) refers to arterial ischemic stroke or sinovenous infarction that occurs between 20 weeks of fetal life to 28 days after birth in infants (Raju, Nelson, Ferriero, & Lynch, 2007). The incidence of perinatal stroke is around 1 in 2500 live births, in near-term and term infants (Cardenas, Rho, & Kirton, 2011; Kirton & deVeber, 2009; Nelson, 2007). Infants with PS frequently show seizures, developmental delay, such as cognitive and motor deficits, and future behavioral problems (Golomb, 2009; Guzzetta et al., 2010; Mercuri et al., 2004; Nelson & Lynch, 2004; Westmacott, Askalan, MacGregor, Anderson, & Deveber, 2010). Among these developmental issues, motor impairment is often detected first, and is a main concern of caregivers and rehabilitation professionals (Kirton, Shroff, Pontigon, & deVeber, 2010). Cerebral palsy (CP) occurs in 30–60% of children with PS. Due to the focal nature of the brain injury, hemiplegia is the most common type of CP (Golomb, Garg, Saha, Azzouz, & Williams, 2008; Mercuri et al., 2004) Most infants with PS who have hemiplegic CP learn to walk independently (Golomb et al., 2003); however, their upper extremity function is limited and greatly affects their participation in daily activities.

Early signs of upper extremity hemiparesis are monitored clinically for infants with PS since they are at high risk for neglect on the affected side of their body and may develop an early hand preference. Reaching with the upper extremities is

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one of the first independent motor skills observed in infancy and can be evaluated before common gross motor milestones, such as crawling and walking. Infants start to reach around 3 to 5 months of age as they learn to explore objects and the environment with their hands (Thelen, Corbetta, & Spencer, 1996). During the process of reaching development, infants increase their reaching frequency from 4 to 6 months of age, and their coordination, measured by the smoothness of the reaching movement, improves from 2 months to 7 months of age (Lee, Ranganathan, & Newell, 2011). Poor reaching has been identified in other infant populations, mostly in the form of delayed onset of reaching. For example, preterm infants, who are at risk for CP, showed fewer reaching numbers and shorter toy-contact durations when compared with infants with typical development (TD) (Heathcock, Lobo, & Galloway, 2008). Infants with Down syndrome showed fewer reaching number and less hand exploration after reaching an object than infants with TD from 4 to 6 months of age (de Campos, da Costa, Savelsbergh, & Rocha, 2013). These findings suggest that atypical reaching and object exploration are detectable between young infants who are at risk for motor delays and disabilities.

The possible contribution of asymmetry and neglect in the development of reaching in infants with PS is different from infants with Down syndrome or infants born prematurely who show global delays in reaching without asymmetry. It is unknown if early trajectory and asymmetry is identifiable in an infants with PS.

TD infants demonstrate symmetry and asymmetry during reaching and grasping tasks over the first year of life. Generally, this behavior is changing and unstable. For example, laterality during reaching is ambiguous when infants are 4 months old (Shiotani et al., 2010). At 5 months of age infants reach equally with the right and left when a toy is presented at midline (Souza, de Azevedo Neto, Tudella, & Teixeira, 2012). From ages 6 to 12 months infants show unstable hand-use preference, meaning they do not show a consistent side of the body for reaching (Ferre, Babik, & Michel, 2010; Lynch, Lee, Bhat, & Galloway, 2008). As such, early stable hand preferences may signal a motor disability. One retrospective study found that infants who later developed spastic hemiplegic CP displayed deficits on the affected side between 3 and 8 months of age. These findings suggest that stable asymmetric upper extremity movements over several months may signal future motor impairment in a high-risk population. However, this retrospective study was limited because it recruited full-term and preterm infants with different types of brain injuries that occurred during pre-/peri-/post-natal stages (Yokochi, Yokochi, & Kodama, 1995). It is unknown if specific asymmetric reaching behaviors can be detected in infants with PS.

Importantly, in high-risk populations, delays in reaching have been identified across several weeks or months instead of at a single time point. This highlights the importance of serially measuring reaching trajectory in identifying atypical development. Atypical reaching may be subtle, and delays can accumulate over time. Identifying poor reaching skills in early infancy may be difficult at a single time point because of the variations in developmental status, and environmental factors such as the position of the infant and size of the toy. Single time point assessments may fail to identify impaired reaching or other motor behaviors. Therefore, using longitudinal assessments to evaluate infants' developmental trajectories is warranted to identify impaired or delayed reaching behaviors in infants with PS.

Children with hemiplegic CP and adults with stroke use their unaffected side more than the affected side resulting in neglect and a lateral preference. As a result, children with hemiplegic CP show limitations in their daily life because of impaired motor function of one side of their body (Klingels et al., 2012). For example, some children with hemiplegic CP have difficulty when holding a big object with both arms; others may have difficulty when performing activities that require specific coordination between both hands, such as buttoning or fastening shoe ties. Although motor dysfunction of the upper extremities is easily observed in children with hemiplegic CP, early detection of asymmetric motor impairments in infants with PS is difficult.

The purpose of this manuscript is to (1) examine the relationship between reaching and age in infants with NS and TD infants; (2) evaluate laterality of reaching behaviors of infants with NS and TD infants from 2 to 7 months of age.

2. Method

2.1. Participants

Sixteen full-term infants with TD and eight full-term infants with PS completed this study. Inclusion criteria were a gestational age at birth of >37 weeks, and focal stroke for the PS group. Infants with TD were reported as typically developing by a parent. Exclusion criteria included genetic disorders, orthopedic or visual impairments that may affect reaching behaviors. Two infants with PS were dropped from final analysis for bilateral stroke involvement on a subsequent MRI. Infants with PS were recruited from the Stroke Clinic at Nationwide Children's Hospital in Columbus, Ohio. The diagnosis of PS was confirmed by magnetic resonance imaging (MRI) and read by a pediatric neurologist. Injury characteristics are summarized in Table 1. In order to observe the emergence of reaching behaviors, infants began the study at approximately 2 months of age in both the TD group ($n = 16$, male = 9, female = 7, mean age = 10.61 ± 1.20 weeks) and PS group ($n = 6$, male = 5, female = 1, mean age = 9.48 ± 1.12 weeks). This study was approved by Nationwide Children's Hospital and The Ohio State University Research Institution Review Boards (IRB). Informed consent was obtained from one parent before the data collection.

2.2. Procedure

Infants were seen for reaching assessment every other week from 2 to 7 months of age for 10 visits. Infants were placed in a custom-made infant chair at 30° from vertical and held with a wide belt across the chest (Fig. 1). A unique toy was