NeuroImage 116 (2015) 168–176

Contents lists available at ScienceDirect

NeuroImage

journal homepage: www.elsevier.com/locate/ynimg

Developmental synchrony of thalamocortical circuits in the neonatal brain

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ARTICLE INFO

Article history:
Received 31 December 2014
Accepted 14 March 2015
Available online 23 March 2015

Keywords:
Diffusion tensor imaging
Neonatal brain
Cortical thickness
Thalamocortical connectivity
Thalamic nuclei

ABSTRACT

The thalamus is a deep gray matter structure and consists of axonal fibers projecting to the entire cortex, which provide the anatomical support for its sensorimotor and higher-level cognitive functions. There is limited *in vivo* evidence on the normal thalamocortical development, especially in early life. In this study, we aimed to investigate the developmental patterns of the cerebral cortex, the thalamic substructures, and their connectivity with the cortex in the first few weeks of the postnatal brain. We hypothesized that there is developmental synchrony of the thalamus, its cortical projections, and corresponding target cortical structures. We employed diffusion tensor imaging (DTI) and divided the thalamus into five substructures respectively connecting to the frontal, precentral, postcentral, temporal, and parietal and occipital cortex. T_2-weighted magnetic resonance imaging (MRI) was used to measure cortical thickness. We found age-related increases in cortical thickness of bilateral frontal cortex and left temporal cortex in the early postnatal brain. We also found that the development of the thalamic substructures was synchronized with that of their respective thalamocortical connectivity in the first few weeks of the postnatal life. In particular, the right thalamo-frontal substructure had the fastest growth in the early postnatal brain. Our study suggests that the distinct growth patterns of the thalamic substructures are in synchrony with those of the cortex in early life, which may be critical for the development of the cortical and subcortical functional specialization.

Introduction

The thalamocortical circuitry stems from the thalamus, a deep gray matter structure that relays and modulates information to and from the cortex. The thalamocortical circuitry undergoes rapid morphological growth to adapt to the needs of numerous sensorimotor, cognitive, and attentional functions in early life (Gilmore et al., 2012; Holland et al., 2014; Qiu et al., 2013). Thalamocortical dysconnectivity, both structural and functional, has been implicated in children with autism spectrum disorder (Nair et al., 2013), attention deficit hyperactivity disorder (ADHD; Bush, 2011; Van Ewijka et al., 2012), and schizophrenia (Jones, 1997; Woodward et al., 2012). Abnormal thalamic development has also been found in preterm infants (Ball et al., 2012; Srinivasan et al., 2007), and survivors often suffer from cognitive and behavioral deficits and have an increased risk of developing autism and ADHD (D'Onofrio et al., 2013; Delobel-Ayoub et al., 2009). It has therefore been suggested that the thalamocortical circuitry might be neural substrates for understanding the biological origin of neurodevelopmental disorders (Marlow et al., 2005; Tillman et al., 2008). Hence, establishing a baseline for normal development of the thalamocortical circuits in early life is clinically relevant to understanding which characteristics of thalamocortical development may be selectively vulnerable to injury and leads to neurodevelopmental disorders.

The development of thalamocortical connections starts prenatally and continues into the neonatal period, which has been demonstrated by histochemical studies in the human newborn cortex (Mrzljak et al., 1988). Abnormal prenatal thalamic development is associated with

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http://dx.doi.org/10.1016/j.neuroimage.2015.03.039
1053-8119/