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Structural connectivity asymmetry in the neonatal brain

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ABSTRACT

Asymmetry of the neonatal brain is not yet understood at the level of structural connectivity. We utilized DTI deterministic tractography and structural network analysis based on graph theory to determine the pattern of structural connectivity asymmetry in 124 normal neonates. We tracted white matter axonal pathways characterizing interregional connections among brain regions and inferred asymmetry in left and right anatomical network properties. Our findings revealed that in neonates, small-world characteristics were exhibited, but did not differ between the two hemispheres, suggesting that neighboring brain regions connect tightly with each other, and that one region is only a few paths away from any other region within each hemisphere. Moreover, the neonatal brain showed greater structural efficiency in the left hemisphere than that in the right. In neonates, brain regions involved in motor, language, and memory functions play crucial roles in efficient communication in the left hemisphere, while brain regions involved in emotional processes play crucial roles in efficient communication in the right hemisphere. These findings suggest that even at birth, the topology of each cerebral hemisphere is organized in an efficient and compact manner that maps onto asymmetric functional specializations seen in adults, implying lateralized brain functions in infancy.

Introduction

The human brain exhibits structural asymmetries to support its specific lateralized functions, such as language and motor control. Such asymmetry in structure is apparent even in early life. But these structural asymmetries at the neonatal period may or may not persist through life. Moreover it is unclear whether structural asymmetry is reflected in differences in connectivity.

In healthy neonates, the left cerebral hemisphere is larger than the right (Gilmore et al., 2007). However, the normal pattern of fronto-occipital asymmetry described in older children and adults, notably larger right than left frontal lobe and larger left than right occipital lobe (Chapple et al., 2004; LeMay, 1976; Sharma et al., 1999; Weinberger et al., 1982) is not present in neonates (Gilmore et al., 2007). Beyond the whole brain level, Witelson and Pallie (1973) revealed a neonatal leftward asymmetry of the planum, a region known to be of significance for language function. Additional support is derived from a diffusion tensor imaging (DTI) technique that characterizes axonal organization of the brain white matter. Structural asymmetries in language- and motor-related fibers (e.g., the parieto-temporal part of the superior longitudinal fasciculus, the corticospinal tract, the superior thalamic radiations) are present in healthy (Dubois et al., 2009) as well as preterm infants (Liu et al., 2010). These findings are similar to the pattern seen in adults, suggesting that the observed neonatal anatomical asymmetry provides a structural basis for the adult pattern of the lateralization of language functions.

Our understanding of the structural asymmetry of the neonatal brain is still largely limited to the level of individual structures. Nevertheless, widespread brain areas are wired in a compact and economic manner and hence can easily transfer information in short and long distances to adapt to cognitive demands (Bullmore and Sporns, 2012). Recent advanced modern neuroimaging techniques allow for non-invasive investigation of the brain connectivity. Using DTI tractography and structural

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