Neonatal Asymmetry between Preterm and Term Neonates:An MRI Structural Network Study

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INTRODUCTION

The hemispheric structural asymmetry of neonatal brain is important to understand early brain development. The structural covariance networks (SCNs) based on graph theory provide an objective insight to understand hemispheric structural asymmetry. Recent studied have revealed structural connectivity asymmetry in full-term neonates by DTI deterministic tractography and structural network analysis. But it is still unclear how it changes between preterm and full-term neonatal brain. In this study, SCNs of preterm and term neonatal brain were constructed based on regional volume correlation. The differences of hemispheric asymmetry between preterm and term neonates were been revealed by the structural network analysis.

MATERIALS AND METIODS

This study was approved by the local institutional review board. The neonates were all sedated (oral chloral hydrate, 25-50 mg/kg) with parental consent before MRI scanning. 11 normal preterm neonates (7 males and 4 females, mean postmenstrual age = 34.08 ± 0.83weeks, PMA range: 33.00 – 35.71 weeks) and 11 normal term neonates (8 males and 3 females, mean postmenstrual age= 41.34 ±0.84weeks, PMA range: 39.86 – 42.57 weeks) were examined. Data were acquired by 3D-T1 FSPGR sequence on a 3T scanner (GE, Signa HDxt) with 8-channel head coil. Acquisition parameters used were as follows: repetition time =10.28ms; echo time =4.616ms; inversion time =400ms, 110-140 slices; voxel size=0.94×0.94×1mm^3, resampling resolution =0.6×0.6×0.6mm^3. Preprocessing of T1 data was performed using Brain Extraction Tool in FMRIB's Software Library (FSL). The neonatal template for registration has 64 anatomically cortical and subcortical regions from neonatal atlas of Johns Hopkins University [1]. The residuals of the regression was taken as corrected cortical volume estimates to model effects of total brain volume, gender, and age. Pearson correlation coefficient [2] was estimated as the connection between cortical volume measures of 11 subjects in each group. The parameters of network, including degree, global efficiency, local efficiency and betweenness centrality, were calculated by Brain Connectivity Toolbox (http://www.nitrc.org/projects/bct/). Permutation test was used to examine significant level of these parameters. Brain network asymmetry was examined by lateralization index (LI) [3] for network measures. LI for a given network measure X was calculated as: $\mathrm{LI(X)} = 100 * \frac{X(right)-X(left)}{X(right)+X(left)}$, where X (right) and X (left) are the given network metrics of the right and left hemispheric networks, respectively. We ordered LI values of betweenness centrality for all nodes and chosen 5 nodes with highest LI, drawn in the network of the left and right hemisphere. The structural brain network were derived from each connection matrix and visualized via BrainNet Viewer (http://www.nitrc.org/projects/bnv/). All the math analyzes were performed using the MATLAB (Mathworks, Natick, MA, USA).

RESULTS

Intra-hemisphere properties and network asymmetry of preterm and term neonates were shown in Table 1. Degree and local efficiency in left hemispheres were higher than that in right hemispheres in both preterm and term neonatal brain networks. Besides, higher absolute LI values of degree and global efficiency were shown in term neonates. Fig.1 showed the brain regions with high absolute LI values of betweenness centrality in preterm and term neonates. For the preterm neonates, the permutation tests showed leftward asymmetry in the regions of thalamus (THA), superior frontal gyrus (SFGdor), cingular gyrus (PoCG), and superior parietal gyrus (SPG), while right cerebellar hemisphere(Cereb), superior occipital gyrus (SOG), parahippocampal gyrus (PHG), angular gyrus(ANG), and gyrus rectus (REC) revealed significant rightward asymmetry. For full-term neonates, inferior occipital gyrus (IOG), supramarginal gyrus (SMG), lyngual gyrus (LING), angular gyrus (ANG), and lateral fronto-orbital gyrus (ORBinf) showed the obvious lateralization in the left hemispheres, however, right asymmetry was exhibited in the middle frontal gyrus (MFG), cingular gyrus (DCG), gyrus rectus (REC), medial fronto-orbaital gyrus (ORBmid), and caudate nucleus (CAU).

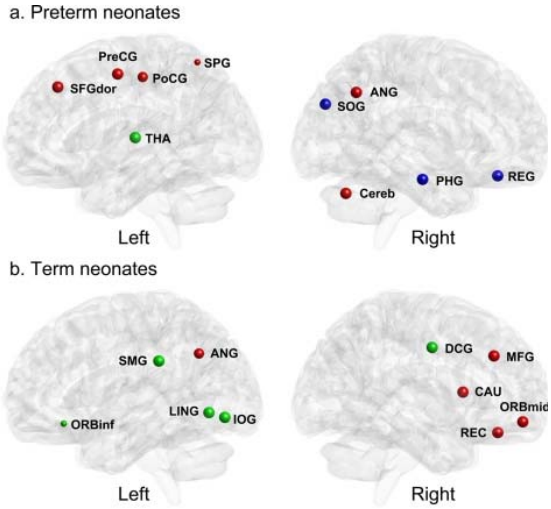

Fig.1: nodes with high LI absolute values of the left and right hemispheres on preterm neonates (a) and term (b) neonates, color-coded by modules and the size for LI absolute values.

Table 1: network measures of the left and right hemisphere

Group	Degree	Global efficiency	Local efficiency
L_preterm	7.3570	0.4734*	0.8754*
R_preterm	6.2500	0.4818*	0.7940*
L_term	8.8750	0.5225*	0.8531*
R_term	5.5625	0.4102*	0.7745*
LI_preterm	-8.2569	0.8740	-4.8780
LI_term	-22.9437	-12.0420	-4.8273

L for left hemisphere; R for right hemisphere; LI>0 suggests the rightward asymmetry; * indicates statistical significance (significance level P<0.05).

DISCUSSIONS AND CONCLUSION

Our study investigated changes of hemispheric asymmetry between preterm and term neonates based on structural covariance networks. Higher degree and local efficiency in left hemispheres than those in right hemispheres indicated the leftward dominant hemisphere both in preterm and term neonates, which is consistent with recent finding [4, 5]. Moreover, when comparing lateralization index between preterm and term neonates, higher absolute LI values of degree and global efficiency in term neonates suggested more evident asymmetry and more efficient information transfer of the left hemispheres. As for the preterm neonates, main brain regions of the left hemispheres involved in motor and sensory functions, whereas right hemispheres were revealed the great asymmetry in the memory function. For the term neonates, functions of visual perception and language processing exhibited in the left hemispheres, while cognitive functions played more crucial roles in the right hemispheres.

In conclusion, based on asymmetry analysis of hemispheric network, our study firstly provided objective evidence for the changes of hemispheric asymmetry between preterm and term neonates. The left hemispheres of full-term neonates have more evident asymmetry than that of preterm neonates. Both the left and right hemispheres in full term brains have evolved into more advanced functions, such as visual, language and cognitive functions.

References 1. Oishi et al., Neuroimage, 2011, 56(1):8-20. 2. Yong He et al., Cerebral Cortex October 2007;17:2407—2419. 3. Iturria-Medina et al., Cerebral Cortex January 2011;21:56—67. 4. Ratnarajah et al., NeuroImage 75 (2013) 195–202. 5. Yong Fan et al., NeuroImage 54 (2011) 1862–1871.