Correlation of brain network metrics with the neuromotor outcome in babies with encephalopathy

Olga Tymofiyeva[1], Christopher P Hess[1], Etay Ziv[1], Sonia L Bonifacio[2], Patrick S McQuillen[2], Donna M Ferriero[2], A James Barkovich[1], and Duan Xu[1]
[1]*Department of Radiology & Biomedical Imaging, UCSF, San Francisco, CA, United States,* [2]*Department of Pediatrics, UCSF, San Francisco, CA, United States*

Introduction. Babies with neonatal encephalopathy are facing the risk of neurological deficits that are difficult to predict. The recently introduced technique for characterizing structural connectivity networks using diffusion MRI [1] can become a new tool for studying the subtle differences in anatomical connectivity of the baby brain. The hypothesis of this study was that baby brain network topology can correlate with developmental deficits. One of the challenges that had to be addressed in this study was the need for an automated unbiased parcellation scheme suitable for the developing brain.

Methods. Diffusion MRI was performed on 17 six-month old babies who had encephalopathy at birth which differently affected their neurological outcome. The babies were scanned on a 3T GE EXCITE MR scanner using half-Fourier SE EPI with a FOV=24 cm, 128x128 matrix, min TE, 30 directions, b-value=700 s/mm^2. To assess structural networks, the following steps were performed.

- To insure data quality, an automated *rejection algorithm* was first employed to identify and discard half-Fourier measurements distorted by motion [2]. The remaining data were corrected for eddy current distortions and affine head motion using FSL [3].
- Tensor-based reconstruction and deterministic whole-brain streamline fiber tractography was undertaken using standard techniques (Diffusion Toolkit [4]).
- The subcortical surface was extracted and two different automated parcellation schemes were applied: *i)* the brain was divided into nodes based on Recursive Zonal Equal Area Sphere Partitioning [5] ("***equipartition***"); *ii)* the brain was partitioned into spatial regions of equal spatial extent along *x*, *y*, and *z* ("***gridded***") (Fig. 1). In both cases the number of nodes was arbitrarily chosen to 40. Both approaches differ from template-based techniques and better suit the rapidly changing developing brain.
- Fiber tracts connecting individual nodes were identified and the connectivity matrix was assembled. The matrices for all babies were binarized using a threshold in the range from 1 (only one fiber track is required to consider two nodes connected) to 10. The thresholds higher than 1 were used to eliminate the apparent connections that may be the result of noise. Network analysis was performed using the Brain Connectivity Toolbox [6].
- The resulting network metrics were correlated with the neuromotor score (NMS) [7] assessed for each baby at the age of 6 months by pediatric neurologists. A higher NMS corresponds to stronger abnormalities.

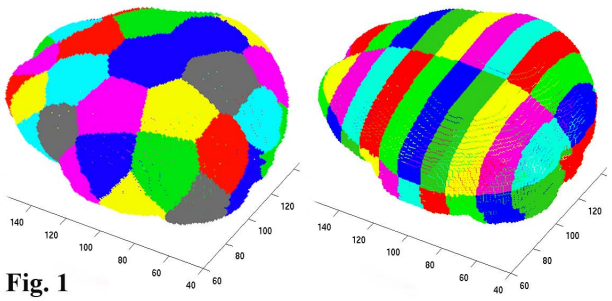

Fig. 1

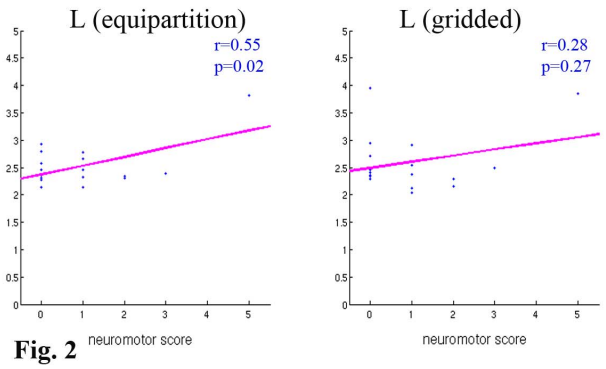

Fig. 2

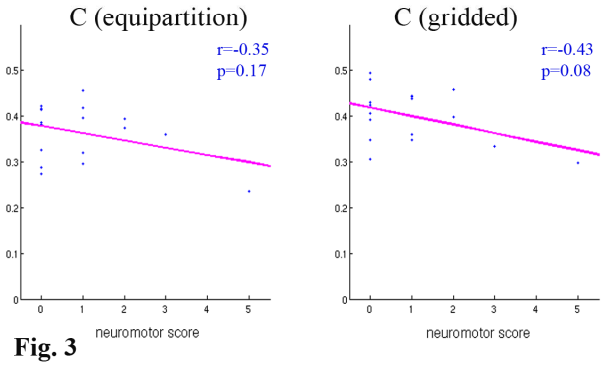

Fig. 3

Results. The characteristic path length *L* (a measure of integration) showed a positive correlation with the NMS for both parcellation schemes (Fig. 2), however, only for the equipartition it was statistically significant for most of the threshold values. The average clustering coefficient *C* (a measure of segregation), on the other hand, decreased with the increasing NMS (Fig. 3). The correlation was significant ($p<0.05$) only for the threshold of 8 with the equipartition scheme. The figures show the results for the threshold of 5.

Discussion. In this study, we correlated some basic properties of the structural brain networks in babies with encephalopathy with the neuromotor outcome at the age of six months. The choice of the threshold for binarizing connectivity matrices affected the statistical significance of the resulting correlation. Nevertheless, a trend to declining brain network integration and segregation could be observed with increasing neuromotor deficits. The suggested parcellation schemes allowed for an automated template-free analysis of the network properties of the developing brain.

Acknowledgements. This work is supported by NIH grants R01EB009756 and P50NS035902.

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