Disturbed Brain Complex Network in Attention-Deficit/Hyperactivity Disorder

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Introduction

Attention-deficit/hyperactivity disorder (ADHD) is a commonly observed neurobehavioral disorders of childhood, but its pathogenic mechanism is still unclear. The graph theory deals with the whole brain as a complex network that owns its unique topological properties. It supplies a novel insight into the investigating of human brain network to find how ADHD affect the brain function. The purpose of this study was to investigate the topological properties of complex network in ADHD patients' brain and find the disturbed connectivity regions using graph theory

Methods

All the resting fMRI data was explored from the 1000 Functional Connectomes Project [1] and the data were gathered from a 3T Siemens scanner. 24 ADHD（19 male and 5 female, age 34.87±9.77） and 24 normal controls（18 male and 6 female, age 34.65±9.15）were chose that had no significant different in age or gender. The preprocessing procedure including brain extraction, motion correction, spatial smoothing (FWHM=6, sigma=2.55), temporal band-pass filtering (0.005<f<0.1Hz), detrending and eliminating redundant information (CSF, white matter and whole brain global signal) were done with FSL and AFNI. Then we analyzed whole brain network consist of 108 regions using graph theory-based approaches[2], binarized the correlation coefficient data and chose the threshold according to $K_P \geqslant 2\log N$ to compute the graph character[3], and finally compared topological properties of two groups using two-sample t-test (P<0.05).

Results and discussion

At a wide range of cost and threshold, statistical analysis revealed that there were significant differences in the topological properties of complex network between the two groups. Compared with normal control group, the ADHD group showed significantly altered topological properties such as decreased global efficiency, longer shortest path, increased modularity, and increased local efficiency and cluster coefficients, as shown is Figure 1. It is clear that there are changes in topological properties of brain network in ADHD group, which shifted to the regular network [4]. A tendency of decreased global efficiency and increased local efficiency of the brain networks was found in ADHD over the whole cost range. It indicates that ADHD patients have lower efficiency in parallel information transfer in the brain network while having higher efficiency in the information exchange among subgraphs. The increased modularity of ADHD group indicates increased numbers of subgraphs were constructed in the brain region. The increased cluster coefficient of single node indicates the connectivity between the node and its neighboring regions become stronger, this also can be proved by the changes of the node's degree. Because the shortest path of ADHD group gets longer, the ability of information integration function is decreased and the nodes' action is intensified. That makes the regions' local efficiency increased and the ability of processing information increased. All these changes of properties of brain function network will lead to decreased ability of integrating information, longer shortest path of information transfer and disrupted brain function.

13 regions showed significant differences between two groups, as shown in Figure 2. At the cost of 0.42, ADHD group demonstrated significant decreases in nodal efficiency in the medial prefrontal, temporal, and occipital cortex regions and increases in the inferior frontal cortex and subcortical regions. This indicates that the topological properties of functional network constructed by these brain regions in ADHD group have also been altered. It is worth noting that the supplementary motor area's nodal efficiency decreased while other regions' nodal efficiency increased in the ADHD group. These regions are believed to be responsible for the ability of the sensorimotor and cognitive processing, including behavioral control and thinking control and focus. The abnormalities of these regions functional connectivity may be the actual reason why ADHD patients exists "attention-deficit", "hyperactive" and "impulsive" problems.

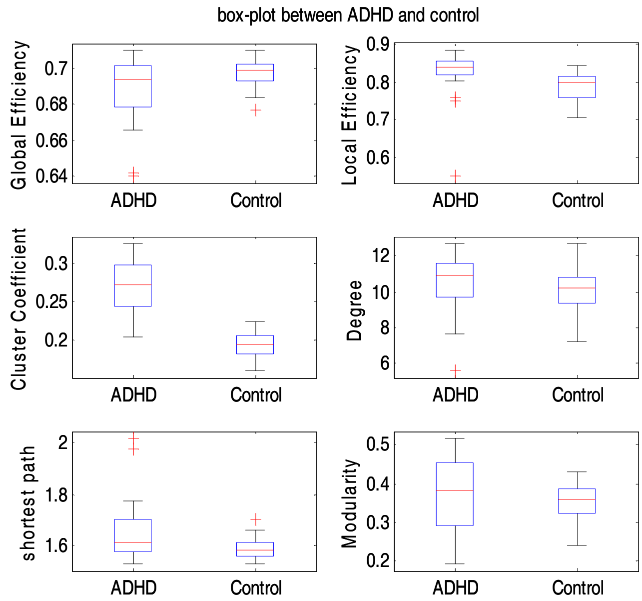

Figure 1. Comparison of topological properties of complex network between ADHD and control group

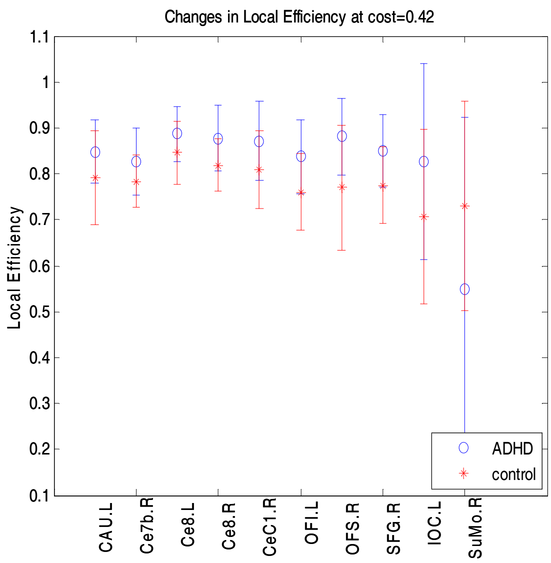

Figure 2. Comparison of local efficiency between ADHD and control group

Conclusion

We proved that the topological properties of complex network were disturbed by ADHD; it had a disruption effect on the topological organization of brain functional networks like global efficiency, local efficiency and cluster coefficient. It was found that ADHD had disrupted some brain regions' function such as frontal cortex and cerebellem, which are associated with the motor and attention. Our results also suggested that the nodal efficiency of brain functional networks is profoundly affected by ADHD. In summary, the graph theory have shown that the pathophysiology of ADHD is associated with the disruption of complex brain functional network and regional abnormalities involving frontal, parietal, temporal, occipital, and subcortical regions, that may lead to the ADHD.

Acknowledgments

This research work was supported by National Natural Science Foundation of Peoples's Republic of China (FC No.81171318，No.30870686) and the Fundamental Research Funds for the Central Universities.

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