Decreased Segregation of Whole-Brain Resting-State Network in Spinal Cord Injury: A Graph Theoretical Analysis

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Introduction

There has been increasing focus on studying large-scale brain networks using graph theory to characterize resting-state functional connectivity. By describing the brain networks in terms of nodes or regions of interest (ROI) and edges or connections between the nodes, various network properties can be evaluated with the help of quantifiable metrics. The present study demonstrates changes to the property of segregation, which evaluates local connectivity of brain networks in spinal cord injury (SCI).

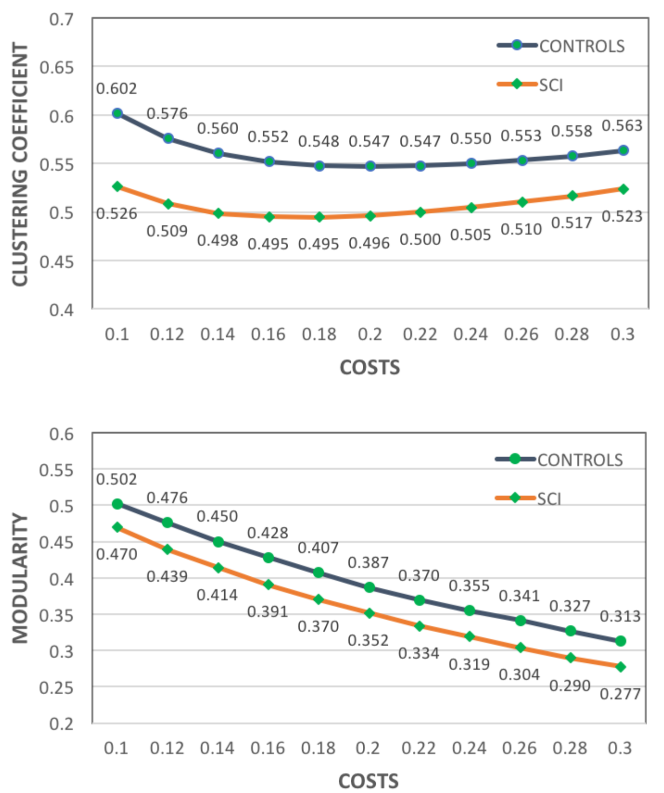
Methods

After obtaining the necessary IRB approval, resting-state functional magnetic resonance imaging (rs-fMRI) was performed on 15 subjects with chronic, cervical SCI (ASIA A) and 15 controls that were intact neurologically. The rs-fMRI data was preprocessed to correct for artifacts and then divided into 264 ROIs based on functional atlas from Power et al. The average time series extracted from each ROI was correlated with every other ROI to obtain connectivity matrices. Correlation coefficient (CC), which measures the connectedness of a node's neighbors amongst each other, and modularity (M), which calculates the extent of division of a network into non-overlapping groups were selected to evaluate network segregation. CC and M were computed at multiple incremental cost thresholds (% of total possible connections) and compared between SCI and controls.

Results

The whole-brain network showed differences between the study groups for both metrics at multiple cost thresholds with CC and M found to be significantly decreased in SCI compared to controls.

Figure 1



Comparison of Clustering Coefficient (CC) and Modularity (M) between the spinal cord injury (SCI) and the controls group at different cost thresholds. Orange and blue lines designate SCI and controls, respectively. The values for CC and M are significantly reduced in SCI at each cost threshold.

Conclusions

The presence of significant differences in the metrics studying system segregation demonstrates the utility of graph theory in evaluating information processing carried out within specialized regions. The findings illustrate that disruption to information transmission between the brain and the spinal cord leads to decreased functional specialization within the whole-brain network. This has the potential to facilitate noninvasive biomarker development for improving the monitoring of functional improvement conferred by various therapeutic approaches.

Learning Objectives

By the conclusion of this session, participants should be able to:

1) Appreciate the role of graph theory in studying functional specialization of brain networks.
2) Understand the impact of spinal cord injury on information processing within segregated regions of the whole brain network.
3) Observe that persistent connectivity alterations are indicative of inherent neural plasticity in the brain.

References

1. Bullmore E, Sporns O. Complex brain networks: graph theoretical analysis of structural and functional systems. Nat Rev Neurosci. Mar 2009;10(3):186-198.
2. Power JD, Cohen AL, Nelson SM, et al. Functional network organization