Large-scale Network Analysis of Whole-brain Resting-state Functional Connectivity in Spinal Cord Injury: A Comparative Study

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Introduction

Graph-theory based network analysis depicts brain as a complex network comprising of nodes and edges that allows for inspection of overall brain connectivity pattern and calculation of quantifiable network metrics. To date, large-scale network analysis has not been applied to resting-state functional networks in spinal cord injury (SCI) patients. The present study applies network analysis to whole brain resting-state functional networks to characterize modular reorganization of constituent nodes and compare network metrics between SCI and control subjects.

Methods

Following IRB approval, 15 subjects with chronic (> 2 years) complete (ASIA A) cervical SCI and 15 controls were scanned. The data was preprocessed followed by parcellation of the brain into 116 regions of interest (ROI) or nodes. Correlation analysis was performed between every ROI pair to construct matrices and ROIs were categorized into distinct modules using MATLAB. Subsequently, local efficiency (LE) and global efficiency (GE) network metrics were calculated at incremental cost (% of total possible edges) thresholds and compared between groups using network based statistic (NBS) method.

Results

The modular organization of functional network grouped SCI and control subjects into 9 and 7 modules respectively (Figure 1). The individual modules differed across groups in terms of number and composition of constituent nodes (Figure 3). LE metric demonstrated statistically significant decrease at multiple cost levels in SCI subjects compared to controls. GE metric did not differ significantly between the two groups (Figure 3).

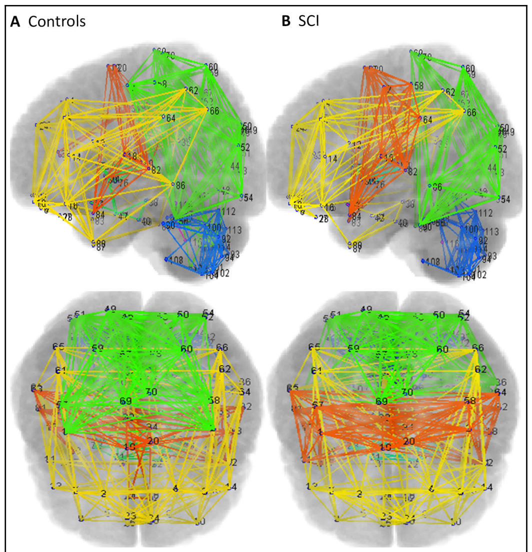

Figure 1: Network view showing modular organization of whole-brain resting-state functional networks in control (A) and SCI (B) subjects. Different color schemes depict individual modular community.

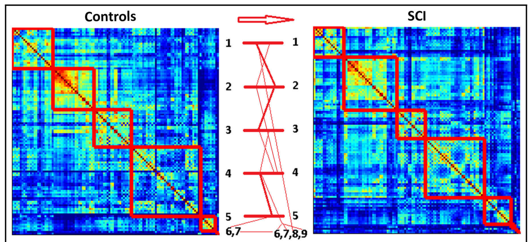

Figure 2: The reorganization of modules based upon correlation coefficient is depicted in the connectivity matrix for control and SCI subjects. The numbers mentioned in the middle correspond to individual modules for each group. Red arrow and red connection lines show the reorganization pattern from controls subjects to SCI subjects. The thickness of each line represents the number of members.

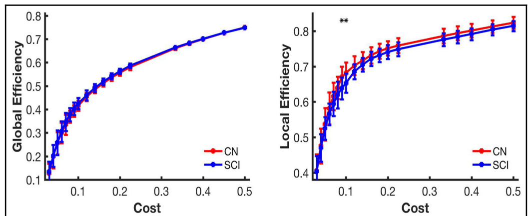

Figure 3: Comparison of network metrics based on graph theoretical approach between controls and SCI subjects at different cost thresholds. Red and blue lines designate control and SCI subject groups respectively and asterisk (*) denotes the threshold values with statistical significance between the groups. Error bars in the figures represent the standard error.

Conclusions

The decreased LE in SCI subjects suggests reduced efficiency of information processing in specialized regions of brain. GE, however does not differ significantly, possibly due to minimal impact of distant SCI on inter-regional connectivity among brain regions. The demonstration of changes in modular organization and localized information processing suggests network analysis can uncover system-wide changes in resting brain functional networks in SCI with potential prognostic and therapeutic implications.

Learning Objectives

By the conclusion of this session, participants will:

1) Be introduced to Large-scale network modeled on graph theoretical approach and its applicability in studying the topological architecture of whole-brain resting-state functional networks.

2) Explore modular reorganization in SCI

3) Analyze whole brain resting state functional changes in SCI using various network metrics.