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DTI Connectome Changes in the Acute Phase of Aneurysmal Subarachnoid Hemorrhage Improve Outcome Classification

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Abstract : Graph-theoretical information from structural connectomes indicated significant connectivity changes and improved acute prognostication in a Random Forest (RF) model in aneurysmal subarachnoid hemorrhage (aSAH), which can lead to significant morbidity and mortality and has traditionally been fraught by poor methods to predict outcome. This study's hypothesis was that structural connectivity changes occur in canonical brain networks of acute aSAH patients, and that these changes are associated with functional outcome at six months. In a prospective cohort of patients admitted to a single institution for management of acute aSAH, patients underwent diffusion tensor imaging (DTI) as part of a multimodal MRI scan. A weighted undirected structural connectome was created of each patient's images using Constant Solid Angle (CSA) tractography, with 176 regions of interest (ROIs) defined by the Johns Hopkins Eve atlas. ROIs were sorted into four networks: Default Mode Network, Executive Control Network, Salience Network, and Whole Brain. The resulting nodes and edges were characterized using graph-theoretic features, including Node Strength (NS), Betweenness Centrality (BC), Network Degree (ND), and Connectedness (C). Clinical (including demographics and World Federation of Neurologic Surgeons scale) and graph features were used separately and in combination to train RF and Logistic Regression classifiers to predict two outcomes: dichotomized modified Rankin Score (mRS) at discharge and at six months after discharge (favorable outcome mRS 0-2, unfavorable outcome mRS 3-6). A total of 56 aSAH patients underwent DTI a median (IQR) of 7 (IQR=8.5) days after admission. The best performing model (RF) combining clinical and DTI graph features had a mean Area Under the Receiver Operator Characteristic Curve (AUROC) of 0.88 ± 0.00 and Area Under the Precision Recall Curve (AUPRC) of 0.95 ± 0.00 over 500 trials. The combined model performed better than the clinical model alone (AUROC 0.81 ± 0.01, AUPRC 0.91 ± 0.00). The highest-ranked graph features for prediction were NS, BC, and ND. These results indicate reorganization of the connectome early after aSAH. The performance of clinical prognostic models was increased significantly by the inclusion of DTI-derived graph connectivity metrics. This methodology could significantly improve prognostication of aSAH.

Keywords : connectomics, diffusion tensor imaging, graph theory, machine learning, subarachnoid hemorrhage
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