

Cerebral Neurovascular Networks May Serve as Potential Targets for Identifying Disorders of Consciousness: A Synchronous EEG-fNIRS Study

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Objective:

Accurate diagnosis of disorders of consciousness (DoC), including minimally conscious state (MCS) and unresponsive wakefulness syndrome (UWS), remains challenging, with a misdiagnosis rate of approximately 41% when using behavioral scales. Resting-state studies reveal widespread disruption of intrinsic and frontoparietal networks in DoC patients. A multimodal technique based on electroencephalography (EEG) – functional near-infrared spectroscopy (fNIRS) leverages the spatio-temporal complementary strengths of both modalities. EEG-fNIRS technique is noninvasive, portable, and ecological, making it suitable for longitudinal monitoring of neuronal and hemodynamic activities simultaneously for patients with DoC. To investigate the differences in neuronal and hemodynamic activities and to characterize neurovascular coupling relationship between healthy control (HC), MCS and UWS using EEG-fNIRS.

Methods:

Resting-state EEG-fNIRS data were acquired over the 13 regions of interest (ROIs) of the brain in patients with DoC. Functional connectivity (FC) based on oxygenated hemoglobin (HbO) and deoxygenated hemoglobin (HbR) were calculated separately for HC, MCS and UWS groups using fNIRS. Additionally, EEG spectral power in delta, alpha, beta, theta, and gamma bands was extracted to characterize the neuronal activities. Correlations of EEG-fNIRS characteristic metrics were calculated to distinguish MCS from UWS and to predict clinical outcomes.

Results:

Multimodal EEG-fNIRS analysis significantly improved the discrimination between MCS and UWS. Notably, both neurovascular coupling and EEG power in the premotor cortex (PMC) and frontopolar cortex (FPC) were significantly higher in MCS than in UWS. MCS patients exhibited elevated EEG beta-band synchronization in several ROIs, including The classifier with multimodal features achieved >90%

accuracy in differentiating MCS from UWS groups, outperforming the classifiers with single-modality model. Importantly, neurovascular coupling features hold promise as a biological marker for the diagnosis and prognostic of patients with DoC.

Conclusion:

Monitoring of neuronal and hemodynamic activities. The results showed that the neuronal and hemodynamic signals over the frontal networks (L_PMC and L_Frontopolar) could distinguish MCS from UWS robustly, addressing limitations of purely behavioral scales. The noninvasive and portable design of EEG-fNIRS facilitates its application for longitudinal bedside monitoring. By combining electrophysiological and hemodynamic biomarkers, this method provides enhanced diagnostic and prognostic precision with clear translational potential.

Key Words: EEG-fNIRS, disorders of consciousness, resting state, neurovascular coupling, non-invasive brain-computer interfaces