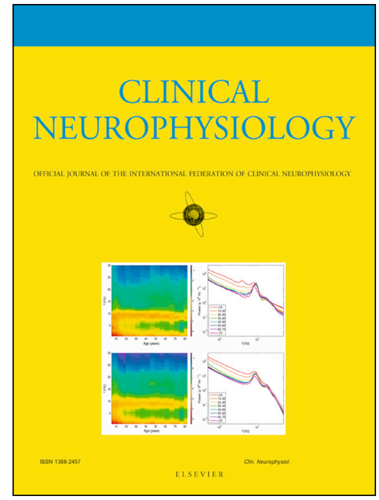

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Intrinsic Network Reactivity Differentiates Levels of Consciousness in Comatose Patients

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Highlights

- Intrinsic brain dynamics distinguish different levels of consciousness in comatose patients.
- Reaching low variance EEG activation patterns becomes harder for lower levels of consciousness.
- The Intrinsic Network Reactivity Index is robust to etiological and pharmacological heterogeneity.

Abstract

Objective: We devise a data-driven framework to assess the level of consciousness in etiologically heterogeneous comatose patients using intrinsic dynamical changes of resting-state Electroencephalogram (EEG) signals.
Methods: EEG signals were collected from 54 comatose patients (GCS$\leq$8) and 20 control patients (GCS>8). We analyzed the EEG signals using a new technique, termed Intrinsic Network Reactivity Index (INRI), that aims to assess the overall lability of brain dynamics without the use of extrinsic stimulation. The proposed technique uses three sigma EEG events as a trigger for ensuing changes to the directional derivative of signals across the EEG montage.
Results: The INRI had a positive relationship with GCS and was significantly different between various levels of consciousness. In comparison, classical band-limited power analysis did not show any specific patterns correlated to GCS.
Conclusions: These findings suggest that reaching low variance EEG activation patterns becomes progressively harder as the level of consciousness of patients deteriorate, and provide a quantitative index based on passive measurements that characterize this change.
Significance: Our results emphasize the role of intrinsic brain dynamics in assessing the level of consciousness in coma patients and the possibility of employing simple electrophysiological measures to recognize the severity of disorders of consciousness (DOC).

Keywords: Consciousness; Traumatic Brain Injury; Coma; Electroencephalography; Intrinsic Dynamics; Intrinsic Network Reactivity Index (INRI)

1. Introduction

Coma and other disorders of consciousness (DOC) is associated with profound reductions in wakefulness and awareness (Bruno et al., 2011; Giacino et al., 2014; Laureys, 2005). Linking these behavioral markers with specific injury attributes remains a persistent clinical challenge (McGee et al., 2016). Electroencephalographic recordings offer the potential to help to disassociate underlying causes of DOC by revealing systematic electrophysiological correlates of injury and behavior (Sitt et al., 2014; Sebastiano et al., 2015). However, patients in coma exhibit substantial heterogeneity in etiology, including injury type and location. Moreover, these patients are often managed with pharmacological agonists that themselves produce electrophysiological effects (Blume, 2006). Thus, realizing the potential of EEG as a diagnostic tool has a number of practical challenges (Wijnen & van Boxtel, 2010; Cruse & Young, 2016).

The most traditional approach to EEG biomarker development involves spectral analysis of band-limited power, i.e., the assessment of rhythmicity and neural oscillations (Buzsáki & Draguhn, 2004), sometimes referred to as Quantitative EEG (QEEG). Examples of this approach for diagnosing disorders of consciousness includes the absence of blink-related delta oscillations in DOC patients (Bonfiglio et al., 2013, 2014), a positive correlation between Coma Recovery Scale-Revised (CRS-R) and ratios between frequencies above 8 Hz and frequencies below 8 Hz (Lechinger et al., 2013), higher theta/alpha and lower delta power of minimally conscious state (MCS) patients compared to vegetative state/unresponsive wakefulness syndrome (VS/UWS) patients (Piarulli et al., 2016), and lower alpha power in UWS and MCS patients (Naro et al., 2016).

However, such an approach could be prone to confound since

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