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Decoding accelerometry for classification and prediction of critically ill patients with severe brain injury

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Our goal is to explore quantitative motor features in critically ill patients with severe brain injury (SBI). We hypothesized that computational decoding of these features would yield information on underlying neurological states and outcomes. Using wearable microsensors placed on all extremities, we recorded a median 24.1 (IQR: 22.8–25.1) hours of high-frequency accelerometry data per patient from a prospective cohort ($n = 69$) admitted to the ICU with SBI. Models were trained using time-, frequency-, and wavelet-domain features and levels of responsiveness and outcome as labels. The two primary tasks were detection of levels of responsiveness, assessed by motor sub-score of the Glasgow Coma Scale (GCSm), and prediction of functional outcome at discharge, measured with the Glasgow Outcome Scale–Extended (GOSE). Detection models achieved significant (AUC: 0.70 [95% CI: 0.53–0.85]) and consistent (observation windows: 12 min–9 h) discrimination of SBI patients capable of purposeful movement (GCSm > 4). Prediction models accurately discriminated patients of upper moderate disability or better (GOSE > 5) with 2–6 h of observation (AUC: 0.82 [95% CI: 0.75–0.90]). Results suggest that time series analysis of motor activity yields clinically relevant insights on underlying functional states and short-term outcomes in patients with SBI.

Severe brain injury (SBI), defined as an acute injury to or illness in the brain that impairs consciousness, imposes the greatest global burden of mortality, long-term disability, and economic cost among all major injury types[1]. Despite other advances in intensive care medicine, existing approaches to predict SBI outcomes, such as recovery of consciousness and functional independence, in the intensive care unit (ICU) are imprecise for individual patients[2] and can raise ethical concerns due to the potential for withdrawal of life-sustaining therapies (WLST)[3]. For example, both general ICU outcome prediction models—e.g., the Acute Physiologic Assessment and Chronic Health Evaluation[4] (APACHE) II—and models developed for specific types of SBI—e.g., the International Mission for Prognosis and Analysis of Clinical Trials in Traumatic Brain Injury[5] (IMPACT) model—are calculated at 24 h after ICU admission and thus disregard the dynamic, heterogenous pathophysiological process that unfolds after SBI[6,7]. At the same time, recent developments in artificial intelligence and big data processing represent an opportunity to enhance SBI patient monitoring with high-resolution, longitudinal waveform data and to improve the precision of SBI prognostication with flexible modeling strategies[8]. Hence, a key focus in the care of SBI is the discovery and validation of quantitative monitoring modalities that improve upon the precision of clinical characterization and the accuracy and reliability of predicted outcomes[9].

For acute neurological disorders, the assessment of motor function provides a unique window into neural systems associated with sensorimotor processing, emotion, coordination, planning, and learning[10–12]. Neurological damage and ICU practices (e.g., sedation, bedrest) are associated with a dramatic reduction in normal

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