Digital signatures for early traumatic brain injury outcome prediction in the intensive care unit

Anil K. Palepu1,6, Aditya Murali1,6, Jenna L. Ballard1,6, Robert Li1, Samiksha Ramesh1, Hieu Nguyen1,2, Hanbiehn Kim1,2, Sridevi Sarma1, Jose I. Suarez2,3,4,5 & Robert D. Stevens2,3,4,5,

1Department of Biomedical Engineering, Whiting School of Engineering, Johns Hopkins University, Baltimore, MD, USA. 2Present address: Department of Anesthesiology and Critical Care Medicine, Johns Hopkins University School of Medicine, Baltimore, MD, USA. 3Department of Neurology, Johns Hopkins University School of Medicine, Baltimore, MD, USA. 4Department of Neurosurgery, Johns Hopkins University School of Medicine, Baltimore, MD, USA. 5Division of Neuroscience Critical Care, Johns Hopkins University School of Medicine, 600 N. Wolfe St, Phipps Suite 455, Baltimore, MD 21287, USA. 6These authors contributed equally: Anil K. Palepu, Aditya Murali, and Jenna L. Ballard. *email: rstevens@jhmi.edu

Traumatic brain injury (TBI) is a leading neurological cause of death and disability across the world. Early characterization of TBI severity could provide a window for therapeutic intervention and contribute to improved outcome. We hypothesized that granular electronic health record data available in the first 24 h following admission to the intensive care unit (ICU) can be used to differentiate outcomes at discharge. Working from two ICU datasets we focused on patients with a primary admission diagnosis of TBI whose length of stay in ICU was ≥ 24 h (N = 1689 and 127). Features derived from clinical, laboratory, medication, and physiological time series data in the first 24 h after ICU admission were used to train elastic-net regularized Generalized Linear Models for the prediction of mortality and neurological function at ICU discharge. Model discrimination, determined by area under the receiver operating characteristic curve (AUC) analysis, was 0.903 and 0.874 for mortality and neurological function, respectively. Model performance was successfully validated in an external dataset (AUC 0.958 and 0.878 for mortality and neurological function, respectively). These results demonstrate that computational analysis of data routinely collected in the first 24 h after admission accurately and reliably predict discharge outcomes in ICU stratum TBI patients.

One potential limitation of existing models is that they do not capture some important predictive features in this population. A more granular analysis of physiological signals (e.g. curve shape, local averages) may reveal important information about a patient’s clinical trajectory. Moreover, recent research indicates that prediction of clinical outcomes and physiological state transitions might be enhanced by training machine learning classifiers because they can effectively model granular relationships in high-dimensional spaces.

Here, we explored electronic health record data to test the hypothesis that early data signatures can differentiate short-term clinical trajectories of TBI patients admitted to the ICU. We demonstrate that information available in the first 24 h of intensive care is predictive of mortality and neurological function at ICU discharge, and that machine learning models can accurately model this relationship. We found that model performance was robust and validated effectively in an independent external population.

1Department of Biomedical Engineering, Whiting School of Engineering, Johns Hopkins University, Baltimore, MD, USA. 2Present address: Department of Anesthesiology and Critical Care Medicine, Johns Hopkins University School of Medicine, Baltimore, MD, USA. 3Department of Neurology, Johns Hopkins University School of Medicine, Baltimore, MD, USA. 4Department of Neurosurgery, Johns Hopkins University School of Medicine, Baltimore, MD, USA. 5Division of Neuroscience Critical Care, Johns Hopkins University School of Medicine, 600 N. Wolfe St, Phipps Suite 455, Baltimore, MD 21287, USA. 6These authors contributed equally: Anil K. Palepu, Aditya Murali, and Jenna L. Ballard. *email: rstevens@jhmi.edu