Deriving predictive pathophysiological markers from ICP analysis

RNDr. Arnošt Mládek, Ph.D.

December 13, 2021

Abstract

Intracranial pressure (ICP) is an irreplaceable neurointensive care parameter and is an area under intensive research. The great diagnostic importance of ICP is underlied by two factors: (1) the central nervous system (CNS) is placed in a rigid cranial vault and even small local expansive processes (e.g. tumors, abscesses, bleeding) may lead to intracranial hypertension; (2) a specific property of the CNS is a rather uniform response to various pathological events since many etiologically heterogeneous diffuse injuries of neural tissue lead to oedema elevating ICP. The complexity of ICP monitoring stems from the neurosurgical insertion of the pressure sensor into the intracranial space and the associated risks of bleeding, neuroinfection and brain tissue damage.

Intracranial pressure is more than just a number on a bedside monitor, even though in clinical practice this simplification is rather common. Similarly to electrocardiogram (ECG) signals whose information content goes well beyond heart rate calculation, understanding of ICP dynamics can provide us with insight into the current clinical status as well as prediction of further evolution.

The mainstay of the dissertation thesis are two first-author articles published in *Scientific Reports* (IF 4.38) a *Neurosurgery* (IF 4.65) journals. Both studies deal with analysis of ICP dynamics and investigate specific markers with clinical implications.

The first of the two studies concerns non-invasive ICP dynamics based on differential geometric analysis of head trembles. We show a universal patient-independent linear correlation between the time of head micro-motions and the ICP time derivative (dICP) maximum, a parameter associated with the biggest cerebrospinal fluid (CSF) flow. We hypothesize and give evidence of a correlation between the abstract dICP waveform and the mean ICP value.

The second study deals with the mathematical analysis of the lumbar infusion test (LIT) ICP signal with LIT being a part of the normal pressure hydrocephalus (NPH) diagnostic battery. The common LIT is evaluated using a single calculated value, the outflow resistance R_{out}, which predicts the CSF shunt implantation response with an accuracy of $\sim 62\%$. We have developed a state-of-the-art machine learning algorithm which takes into account up to 48 ICP waveform features and classifies the patient as (un)suitable for permanent CSF drainage with an accuracy of $\sim 82\%$. The designed classifier has the potential to fully replace the 5-day external lumbar drainage (ELD) associated with the risk of infection, intracranial hypotension and financial costs.