Near-infrared spectroscopy for noninvasive intracranial pressure monitoring

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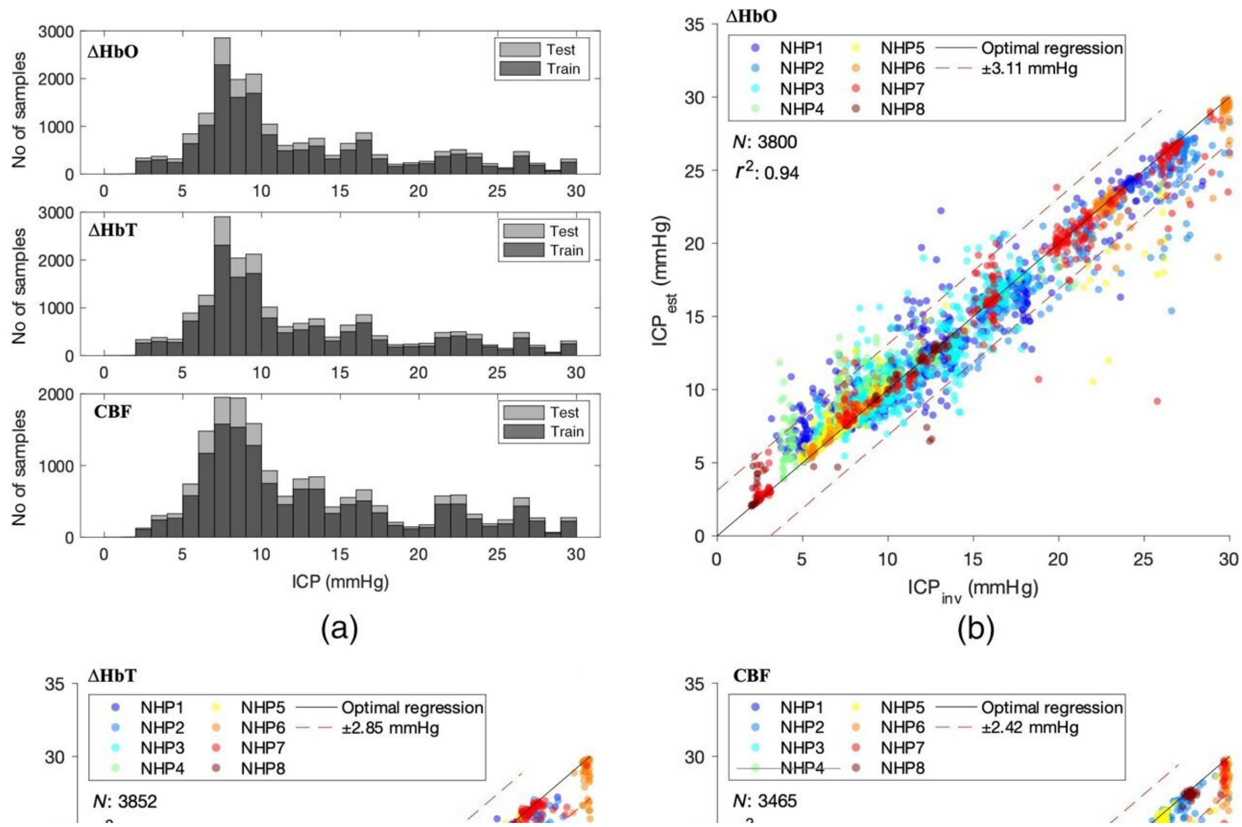

The CMU research team evaluated ICP estimator performance on NIRS-derived average cardiac waveforms (ΔHbO and ΔHbT) against its performance on DCS-based average cardiac waveforms (cerebral blood flow or 'CBF'). (a) Histogram of ICP distribution for both train and test sets across all three modalities. More data were available at lower ICP values, especially between 5 and 10 mmHg. (b)–(d) Correlation plots for ΔHbO, ΔHbT, and CBF. Strong coefficient of determination (r2) for all methods indicates that the model performs well on ICP estimation. Credit: Relander et al, *Neurophotonics* (2022). DOI:

10.1117/1.NPh.9.4.045001.

An increase in intracranial pressure (ICP) is a dangerous condition that can be caused by brain bleeds, a brain tumor, cerebral edema, traumatic brain injury, and hydrocephalus. ICP monitoring is thus a key aspect of patient care in patients with these disorders. Additionally, ICP measurements are relevant when estimating cerebral perfusion pressure (CPP), an indicator of cerebral autoregulation (CA). CPP is linked to neuronal function and neurovascular coupling, and CA defines how the brain maintains a constant blood flow.

Given these broad implications and applications in clinical decision making, precise ICP monitoring is a vital patient management tool. While current tools for ICP monitoring are precise, they can cause hemorrhage or infections and are time-consuming. Although noninvasive alternatives exist, they have limitations such as poor generalizability, low predictive capacity, and a lack of reliability. Thus, diffuse correlation spectroscopy (DCS) and near-infrared spectroscopy (NIRS) are emerging as promising noninvasive solutions. Notably, NIRS has several advantages over other noninvasive methods—low cost, bedside compatibility for long-term and continuous monitoring, along with user independence.

In a new study published in *Neurophotonics*, researchers at Carnegie Mellon University (CMU) successfully deployed a NIRS device to continuously monitor hemoglobin concentration changes. The team built on previous research where they estimated ICP from cardiac waveform features measured using DCS, and also identified the correlation between relative changes in oxyhemoglobin concentration and ICP. But how were they able to measure ICP using the NIRS data? First author on the study, Filip Relander, explains, "We developed and trained a random forest (RF) regression algorithm to correlate the morphology of cardiac pulse waveforms obtained through NIRS with intracranial pressure."

To validate their algorithm, they conducted preliminary tests in a preclinical model. They measured fluctuations in invasive ICP and arterial blood pressure while profiling the changes in hemoglobin concentrations. Following this, they examined the performance of signals derived from the hemoglobin concentration and CBF to accurately verify the precision of their algorithm.

From a proof-of-concept standpoint, the results were very promising. There was a high correlation between the ICP estimated using the RF algorithm and the actual ICP measured using invasive techniques. "We showed, by validating the findings with invasive ICP data, that the trained RF algorithm applied to NIRS based cardiac waveforms can be used to estimate ICP with a high degree of precision," explains Jana Kainerstorfer, Associate Professor of Biomedical Engineering at CMU and senior author of the study. Furthermore, the results indicated that the RF algorithm could interpret waveform features extracted from both NIRS and DCS, highlighting its usability.

The parameters used in the algorithm can be obtained from NIRS measurements, combined with electrocardiograms and mean arterial blood pressure, which are regularly used for clinical evaluation. Thus, if this RF-based platform can produce robust ICP measurements in subsequent human trials, its potential for clinical use would be tremendous. According to *Neurophotonics* Associate Editor Rickson C. Mesquita, Professor at the University of Campinas, "Assessing ICP noninvasively is of great value for monitoring patients in a critical condition, such as those in the intensive care unit. The future of NIRS in this space is exciting."

More information: Filip A. J. Relander et al, Using near-infrared spectroscopy and a random forest regressor to estimate intracranial pressure, *Neurophotonics* (2022). DOI: 10.1117/1.NPh.9.4.045001

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