Characterizing Near-Infrared Optical Density Measurements in Traumatic Brain Injury: Stability, Confounders, and Depth Limits

Adrian Curtin[1], Bartu Atabek[1], Shannon W. Stephens[2], Joshua Richman[2], Elizabeth Liptrap[2], Jonathan Black[2], Alex Valadka[3], John B. Holcomb[2], Jan O. Jansen[2], Hasan Ayaz[1] on behalf of the MOBI study investigators

[1]School of Biomedical Engineering, Science and Health Systems, Drexel University, Philadelphia, PA, USA

[2] Center for Injury Science, University of Alabama at Birmingham, Birmingham, Alabama, USA

[3] Department of Neurological Surgery, University of Texas Southwestern Medical Center, Dallas, Texas, USA

Synopsis

Near-infrared optical density (OD) measurement properties of the InfraScanner 2000 were characterized in 200 TBI patients from the MOBI-1 multi-center study. Serial measurements showed high temporal stability (99.9% of regions coefficient of variation [CV] <0.25). Hair characteristics were the dominant confounding factor, with thick dark hair elevating baseline OD by approximately 40%. Bilateral symmetry was strong (R^2 = 0.65–0.79), supporting spatial prediction of expected values. Deep-only bleeding produced minimal OD elevation, consistent with the 3.5 cm detection depth boundary.

Background

The InfraScanner 2000 is a portable near-infrared spectroscopy device that measures optical density (OD) across eight bilateral brain regions for intracranial hematoma detection (Ayaz et al., 2019; Robertson et al 2010). The device is FDA-cleared for point of care hematoma detection, but serial monitoring for hematoma expansion (Jansen et al., 2025) requires characterization of measurement stability, confounding factors, and detection boundaries. Here we present the first analysis of these measurement properties in a large multi-center TBI cohort.

Methods

Serial Infrascanner measurements from 200 patients enrolled across 10 Level I trauma centers in the MOBI-1 study (mean 2.9 scans per patient) were analyzed. Temporal stability was assessed using the coefficient of variation (CV) across repeated measurements within each brain region. A linear mixed-effects model trained on 937 confirmed-healthy brain regions was used to quantify the influence of demographic and hair characteristics on baseline OD. Bleeding depth effects were evaluated by comparing OD in regions with shallow (≤3.5 cm) versus deep (>3.5 cm) intracranial hemorrhage. Inter-regional correlations were quantified across all 28 region pairs.

Results

Temporal stability was high: 99.9% of regional measurement series had CV <0.25, with mean CV ranging from 0.029 (frontal) to 0.044 (occipital). Hair color produced a monotonic OD gradient from gray (+0.06 units) through brown (+0.84) to black (+1.12), and thick hair added +0.41 units versus thin hair. The combined effect of thick, dark hair elevated baseline OD by approximately 40%. Age, race, and sex effects were comparatively small (<0.1 units after controlling for hair). Bilateral symmetry correlations (R^2 = 0.65–0.79) and within-hemisphere correlations (R^2 = 0.70–0.89) supported spatial prediction of expected regional OD values. Regions with deep-only bleeding showed minimal OD elevation (Cohen's d = −0.25 versus healthy tissue), consistent with the 3.5 cm detection depth boundary. Occipital regions had reduced measurement quality (66.8% of patients with >50% missing data) due to supine positioning, cervical spine immobilization devices, and hair interference. Frontal and temporal

regions had the highest bleeding prevalence (68% and 62% of patients, respectively) and best measurement reliability.

Discussion

Near-infrared OD measurements were temporally stable and sufficient for serial monitoring. Hair characteristics introduced substantial baseline variation that needs to be corrected through demographic normalization to avoid false negatives in patients with thick, dark hair. The confirmed 3.5 cm depth limitation means that device performance should be evaluated against shallow cortical bleeding rather than total hematoma volume. The bilateral and within-hemisphere correlations provide a basis for spatial anomaly detection, where deviations from expected symmetry patterns may indicate lateralized pathology. These properties inform the design of detection algorithms and clinical deployment protocols for NIRS-based hematoma screening in acute TBI.

Disclosures

This project was sponsored by the Government under Other Transaction Number W81XWH-15-9-0001. The views and conclusions contained herein are those of the authors and should not be interpreted as necessarily representing the official policies or endorsements, either expressed or implied, of the U.S. Government. H. Ayaz was involved in the technology development of Infrascanner and was thus offered equity in the startup firm InfraScan. J. Jansen and S. Stephens are consultants for InfraScan. J. Jansen, S. Stephens, J. Holcomb, J. Richman, E. Liptrap, A. Valadka and J. Black received grant funding from the Medical Technology Enterprise Consortium, as well as study support from Infrascan, to conduct the MOBI studies.

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