# MINIMALLY INVASIVE MONITORING OF THE CENTRAL NERVOUS SYSTEM

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Biomedical applications of diffuse optics have primarily focused on applications with non-invasive, endoscopic, or intraoperative patient interfaces ("probes"). While these tools have made significant impact, these interfaces have well known challenges (e.g., impact of superficial tissue on signal, limited endoscopic access, necessity of open surgical field). However, there are a range of conditions in which unfortunately serious and common sequelae drive the use of invasive monitoring tools as standard-of-care. This is particularly true in the context of preventing additional injury to the central nervous system (CNS). The most common of these standard-of-care invasive tools may be intracranial pressure (ICP) monitors placed into the brain following, e.g., severe traumatic brain injury (TBI). Additionally, the risk benefit ratio of a *minimally* invasive probe may permit expansion of applications to conditions in which standard of care monitoring with non-invasive tools is inadequate (e.g., spinal cord injury, SCI). Extending the use of surgically-placed minimally invasive probes into the post-operative period may allow enhanced monitoring during this potentially risky period.

We have developed minimally invasive diffuse optical probes for the central nervous system. These probes are placed on or under the dura covering the brain or spinal cord via epidural or open approaches and may be left in place for post-surgical monitoring. Our current device utilizes diffuse optical and correlation spectroscopies, enabling effectively continuous (>0.3 Hz) measurement of CNS blood flow and oxygenation during physiological manipulations and aortic occlusion in large animal models.

In the spinal cord, we have demonstrated this device in large animal models of aortic surgery[1] and scoliosis.[2] In comparison to standard-of-care motor or somatosensory evoked potentials (MEP, SEP) our device is capable of more rapid identification of ischemia and provides the unique capacity to *localize* the ischemic region of the spinal cord.[1] Potential clinical additional applications include acute and subacute management of severe TBI and SCI.

1 Busch, D.R., Lin, W., Goh, C.C., Gao, F., Larson, N., Wahl, J., Bilfinger, T.V., Yodh, A.G. and Floyd, T.F. Towards rapid intraoperative axial localization of spinal cord ischemia with epidural diffuse correlation monitoring. PLoS One 16, e0251271, doi:10.1371/journal.pone.0251271 (2021). PMCID: PMC8109798.

2 Busch, D.R., Lin, W., Cai, C., Cutrone, A., Tatka, J., Kovarovic, B.J., Yodh, A.G., Floyd, T.F. and Barsi, J. Multi-Site Optical Monitoring of Spinal Cord Ischemia during Spine Distraction. J. Neurotrauma 37, 2014-2022, doi:10.1089/neu.2020.7012 (2020). PMCID: PMC7470219.

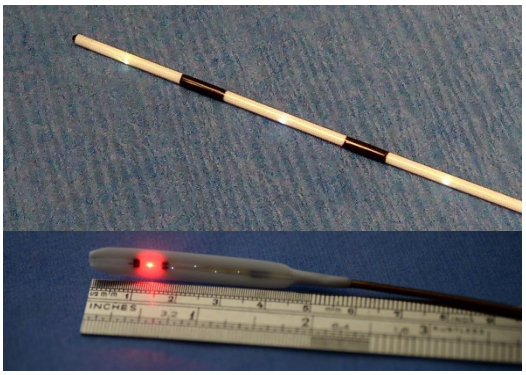

*Figure 1 – Prototype minimally invasive probes. (top) Multi-site spinal cord probe for percutaneous placement. (bottom) Paddle probe for open placement on the dura.*