Laser speckle contrast and oxygen imaging

- Characterization of spreading depolarizations in swine following superior sagittal sinus occlusion: a novel gyrencephalic model study
- Research on the classification of early-stage brain edema by combining intrinsic optical signal imaging and laser speckle contrast imaging
- Endothelial NOX4 aggravates eNOS uncoupling by decreasing dihydrofolate reductase after subarachnoid hemorrhage
- Intracranial pressure spikes trigger spreading depolarizations
- Increases in Microvascular Perfusion and Tissue Oxygenation via Vasodilatation After Anodal Transcranial Direct Current Stimulation in the Healthy and Traumatized Mouse Brain
- A large, switchable optical clearing skull window for cerebrovascular imaging
- The influence of norepinephrine and phenylephrine on cerebral perfusion and oxygenation during propofol-remifentanil and propofol-remifentanil-dexmedetomidine anaesthesia in piglets
- The effect of dexmedetomidine on cerebral perfusion and oxygenation in healthy piglets with normal and lowered blood pressure anaesthetized with propofol-remifentanil total intravenous anaesthesia

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Overview and Applications

1. Laser Speckle Contrast Imaging (LSCI) LSCI is a non-invasive, high-resolution optical imaging technique used to measure blood flow dynamics in real time. It is based on the scattering of coherent laser light by moving red blood cells, creating a speckle pattern that changes over time. These changes can be analyzed to infer blood flow velocity.

Principle: - A laser illuminates the target tissue, and a camera captures the speckle pattern formed by scattered light. - Moving red blood cells cause fluctuations in the speckle pattern, which can be quantified to estimate **perfusion (relative blood flow).** - Faster movement = More blur in the speckle pattern = Higher perfusion.

Applications: - **Neurosurgery & Neurology:** Monitoring **cerebral blood flow (CBF)** in stroke, brain tumors, and vascular surgeries. - **Dermatology & Wound Healing:** Assessing **microcirculation in burns, diabetic ulcers, and skin grafts.** - **Cardiovascular Research:** Studying **peripheral vascular diseases, ischemia, and reperfusion injury.** - **Ophthalmology:** Evaluating **retinal blood flow in glaucoma and diabetic retinopathy.** - **Intraoperative Monitoring:** Used during **bypass surgery** or aneurysm clipping to ensure adequate perfusion.

Advantages: - Real-time imaging with high temporal and spatial resolution. - Non-invasive and does not require contrast agents. - Suitable for both **animal studies** and **clinical applications.**

Limitations: - Provides **relative blood flow measurements** rather than absolute values. - Sensitive to **motion artifacts**, requiring careful stabilization. - Limited penetration depth (primarily surface-level tissue imaging).

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2. Oxygen Imaging Oxygen imaging refers to techniques used to visualize and measure **oxygen levels (O_2) in tissues**, providing insight into tissue metabolism and hypoxia.

Techniques: - **Optical Oxygen Sensors (Phosphorescence or Fluorescence-Based)**

1. **Phosphorescence Quenching (e.g., Oxygen-Sensitive Dyes)**
   1. Oxygen-sensitive phosphorescent molecules change their fluorescence lifetime based on oxygen concentration.
   2. Used in **tumor hypoxia, ischemic brain injury, and wound healing.**
2. **Fluorescence-Based Probes**
   1. Fluorescent dyes (e.g., Pt-porphyrins) provide oxygen mapping in vivo.

- **Photoacoustic Imaging (PAI)**

1. Uses pulsed laser excitation to generate ultrasound waves based on light absorption by hemoglobin.
2. Measures **oxygen saturation (sO_2)** non-invasively in deep tissues.
3. Applications: **Tumor hypoxia, stroke, and retinal oxygenation.**

- **Near-Infrared Spectroscopy (NIRS)**

1. Detects changes in **oxyhemoglobin (HbO_2) and deoxyhemoglobin (Hb)** levels.
2. Used in **brain monitoring (functional NIRS - fNIRS), muscle metabolism, and neonatal care.**

- **Magnetic Resonance Oxygen Imaging (MRI-Oximetry)**

1. Uses blood oxygen level-dependent (BOLD) contrast to assess tissue oxygenation.
2. Common in **brain imaging, tumor hypoxia studies, and cardiovascular diseases.**

Applications of Oxygen Imaging: - **Neurosurgery & Stroke:** Detecting brain hypoxia and ischemia. - **Oncology:** Identifying tumor hypoxia for radiation therapy planning. - **Cardiology:** Assessing myocardial oxygenation post-infarction. - **Wound Healing & Peripheral Vascular Disease:** Evaluating tissue oxygenation.

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Integration of LSCI and Oxygen Imaging - **LSCI provides blood flow data**, while **oxygen imaging gives metabolic and perfusion insights**. - **Combining both** can offer a more comprehensive view of **tissue health, ischemia, and therapeutic responses**. - Used together in **stroke research, intraoperative neurovascular monitoring, and cancer treatment assessment**.

Cerebral sinus thrombosis, which constitutes a small percentage of all strokes, usually affects young individuals and can lead to venous stroke. Ischemic and hemorrhagic Stroke are associated with Spreading Depolarization (SD) waves in brain tissue, propagating through the affected areas and causing a transient disruption of ionic homeostasis and neuronal function. This interaction highlights the complexity of the neurological consequences associated with SD.

Sanchez-Porras et al. investigated the occurrence of SDs following the occlusion of the superior sagittal sinus (SSS) in a gyrencephalic model, specifically swine. To instigate an occlusion, they surgically clipped the middle third of the SSS. The animals were grouped and monitored using one of three methods: electrocorticography (ECoG) alone, ECoG with intrinsic optical signal (IOS) imaging, or ECoG in conjunction with laser speckle contrast and oxygen imaging (LSCI). Post-mortem, the brains were analyzed using 2,3,5-triphenyl tetrazolium chloride (TTC) staining to check for venous infarction. Our results confirmed the spontaneous occurrence of SDs in the gyrencephalic swine brain after SSS occlusion, which was detectable via all monitoring methodologies. SD activity was most frequent in the first-hour post-occlusion, subsequently diminishing. IOS imaging identified four unique hemodynamic responses, while TTC staining indicated no infarction. This research is the first to document SDs in the gyrencephalic swine brain following SSS occlusion, laying the groundwork for future investigations in both animal models and human clinical studies [1].

[1]

Sanchez-Porras R, Ramírez-Cuapio FL, Gutiérrez-Herrera MA, Puig-Lagunes ÁA, Albiña-Palmarola P, López-Navarro JM, Suárez-Gutiérrez MA, Díaz-Peregrino R, Sandoval-Lopez DA, Fischer G, Vazifehdan F, Woitzik J, Santos E. Characterization of spreading depolarizations in swine following superior sagittal sinus occlusion: a novel gyrencephalic model study. Thromb J. 2025 Feb 12;23(1):15. doi: 10.1186/s12959-025-00689-w. PMID: 39940023.