Monitoring of neurovascular coupling using moorVMS-OXY

Application note #112

Application

Neurovascular coupling is one of the key concepts for the investigation of brain functions. The higher rate of oxygen metabolism of cortical tissue following the onset of a stimulus is commonly correlated with an increase in blood flow. This increase is linked to a higher oxygen supply by the blood to the tissue and compensates the higher oxygen extraction. Consequently, there is an increase in oxygenation, i.e. an increase in the concentration of oxygenated haemoglobin and a decrease in the deoxygenated haemoglobin. The BOLD (Blood Oxygen Level Dependent) contrast in functional magnetic resonance imaging (fMRI) exploits this for an imaging of cortical function. Tissue oxygen monitoring using white-light reflective spectroscopy is well suited to record local changes in oxygenation, and functional related changes in haemoglobin from the opened cortex. Contrary to BOLD which is sensitive to changes in deoxygenated haemoglobin concentrations, the optical tissue oxygen monitoring is able to retrieve both the oxygenated and deoxygenated haemoglobin concentrations. Additionally, the oxygen saturation of the haemoglobin in the microcirculation can be obtained.

Equipment Required

The following equipment is required for cerebral blood flow imaging:

- moorVMS-OXY tissue oxygen monitor
- moorVMS-PC Windows™ software and PC
- OP3 or CP3 blunt needle, end delivery optic probe
- O2 consumption
- blood flow
- oxyHb
- deoxyHb
- SO2
- totalHb
- deoxyHb
- oxyHb
- SO2
- totalHb
- neuron
- vessel

Method

- Animal preparation:
  - Preparation of a surgically thinned skull – the moorVMS-OXY can then monitor haemoglobin through the translucent surface (Hashimoto et al., 2010; Wang et al., 2010).
  - Alternatively, monitoring through an optical glass window positioned over the cortex (Lindauer et al., 1999).
  - Controlled physiology conditions (blood pressure, temperature etc.) are crucial for reliable results.

- Place an OP3 or CP3 optic probe over the cortex area to be stimulated as shown below. A standard mechanical micromanipulation can serve for a precise positioning.

Running the moorVMS-PC measurement software and record tissue oxygen saturation and haemoglobin concentrations due to cortical activation.

The figure below displays the functional response in rat brain monitored through a closed cranial window over the area of the somatosensory cortex. Six electrical forepaw stimulations (electrical current at 3 Hz for durations of 16 s each) were used to stimulation. Each stimulus is followed by an increase in oxyHb and a decrease in deoxyHb concentration. This corresponds to an increase in both tissue oxygen saturation (SO2) and total haemoglobin concentration (totalHb).
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Figure 1 principle of neurovascular coupling: neuronal activation results in a higher consumption of oxygen which is supplied by the microcirculation. Following a neuronal stimulus, the tissue blood flow and the concentrations of oxygenation and deoxygenated haemoglobins (oxyHb, deoxyHb) are modulated.

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Figure 2 placement of the optic probe: the tip of the probe is either in direct contact with the tissue (thinned skull) or positioned above an optical cranial window.
Figure 3 screen shot of the online data following six cortical activations: recorded time course of oxygenated and deoxygenated haemoglobin concentration (oxyHb, deoxyHb), the tissue oxygen saturation (SO2) as well as the total haemoglobin concentration (data by U. Lindauer, TU Munich).

Practical Suggestions

- Measurement of haemoglobin and oxygen saturation with the moorVMS-OXY can easily be combined with blood flow recordings by laser Doppler monitor (moorVMS-LDF). The data of both instruments are acquired in the same moorVMS-PC software and Moor Instruments supplies an optical probe (CP3) for the combined measurement.
- Haemoglobin data can be supplemented by recording the electrical activity. E.g. Royl et al. (2008) report on a correlation of haemoglobin and somatosensory evoked potentials.
- The moorVMS-OXY data acquisition module provides the digital trigger input/output which can be used to synchronise electrical stimulus and blood flow and oxygen measurement. Alternatively, use the analogue output of the moorVMS-OXY for data integration with other data acquisition system.
- Combining haemoglobin and blood flow monitoring, the cerebral metababolic rate of oxygen (CMRO2) can be calculated (Royl et al., 2008, Leithner et al., 2009).
- Haemoglobin monitoring can serve to study the effects of physiological conditions like temperature, pH or oxygen supply conditions on neurovascular coupling (see e.g. Lindauer et al., 2003, 2010, Füchtemeier et al., 2010).

Publications


Further Reading

moorVMS-OXY and moorVMS-PC user manuals for instrument operation and cleaning and handling of optic probes. www.moor.co.uk - information about moorVMS-OXY, moorVMS-LDF, moorVMS-DAQ and optic probes. Please feel free to consult sales@moor.co.uk for further advice or support with issues not covered in this application note and details of other application notes using the moorVMS-OXY.

Important Disclaimer: This information is provided to further clinical research into diagnostic capabilities of white light spectroscopy. The moorVMS-OXY is CE marked for human. Equipment with a current service record should only be used.

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Figure 3: Screen shot of the online data following six cortical activations: recorded time course of oxygenated and deoxygenated haemoglobin concentration (oxyHb, deoxyHb), the tissue oxygen saturation (SO2) as well as the total haemoglobin concentration (data by U. Lindauer, TU Munich).

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- The moorVMS-DAQ data acquisition module provides the digital trigger input/output which can be used to synchronise electrical stimulus and blood flow and oxygen measurement. Alternatively, use the analogue output of the moorVMS-OXY for data integration with other data acquisition system.
- Combining haemoglobin and blood flow monitoring, the cerebral metabolic rate of oxygen (CMRO2) can be calculated (Royl et al., 2008, Leithner et al., 2009). Haemoglobin monitoring can serve to study the effects of physiological conditions like temperature, pH or oxygen supply conditions on neurovascular coupling (see e.g. Lindauer et al., 2003, 2010, Füchtemeier et al., 2010).

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