Evaluation of Haemoglobin and Cytochrome responses using a Broadband Time Resolved NIRS system

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Introduction

Focus of our group A,B,C

To develop new instruments and methods in order to retrieve information about cerebral **hemodynamics** and **metabolism**, on healthy subjects or at the patient bedside using NIRS

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**Metabolism and cytochrome-c-oxidase**¹

- Cytochrome c oxidase (CCO) is the terminal enzyme of mitochondrial electron transport chain.
- Redox state of CCO is a non-invasive marker of cellular oxygen metabolism
- The broadband NIRS measurement of [oxCCO] is highly associated with MRS marker of metabolism¹

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¹ Bainbridge et al.(2014). *NeuroImage*, 102(P1), 173–183
Introduction

Measurement Gold standard:

- Broadband Continuous Waves (CW) systems

- Multiwavelength will allow the quantification of [Hb] [HbO$_2$] [oxCCO]
  - 4/5 wavelength: error < 4%
  - 8 wavelength: error < 2%

- Use time resolved system to improve the accuracy of the quantification

Aims

❖ To describe the system
❖ First *in-vivo* study to validate the ability of a multi-wavelength Time Resolved NIRS system to monitor both hemodynamic and metabolic responses on a muscular cuff occlusion

➢ Retrieve $\Delta[Hb]$ $\Delta[HbO_2]$ and $\Delta[oxCCO]$ during a large Haemoglobin change

❖ Good test for the crosstalk

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**Crosstalk**

**No crosstalk**
Methods

System overview

✓ Time Resolved and Multi-wavelength capabilities\textsuperscript{5}

System overview

✓ Time Resolved and Multi-wavelength capabilities

Source part:

- 2 sources
- Discrete number of wavelength (AOTF)
  - Fast switching mode (100Hz) : 16 λ / Source
- Few mW / λ
- FWHM : 2-4 nm

System overview

- Time Resolved and Multi-wavelength capabilities

Detection part:
- 4 detectors
  - 4 Photomultipliers (PMT) + Variable Optical Attenuator
  - 1 router + 1 acquisition TCSPC card
- Good sensitivity until 870 nm
- Overall spectral bandwidth: 650 / 870 nm

Methods

➢ Transportable

AOTF
AOTF drivers
Laser
Computer
Power stage

Software

Detection Part
AOTF

A : Front side (Operator) B : Back side (Subject)
Methods – I Cuff Occlusion

Experiment:
- Muscular cuff occlusion (arterial) on the left arm
  - 5 min rest
  - 5 min occlusion
  - 5 min recovery
- 6 subjects (2F / 24-29 years)

Settings:
- 1 source / 4 detectors (same area)
- 16 wavelengths
- (780-870 nm, every 6 nm)
- IT: 50 ms/λ
- Acquisition frequency 1Hz
Methods – I Cuff Occlusion

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Concentration changes calculation

We used 2 methods to recover the concentration changes:

I - Modified Beer Lambert Law (UCLn)

- Classical method with CW systems
- Uses change in attenuation
- Need to provide the pathlength (DPF)

- True Pathlength used: Calculated for each subject and each wavelength form the mean time of flight.

II - Change in coefficient of absorption

- Fitting procedure to extract absorption and scattering coefficients
- Calculation based on $\Delta \mu_a$
- Lower SNR, averaging over 10 time points

- Good SNR
Results – I Cuff Occlusion

Grand Average over all subjects and Detectors (n=24)

Method 1 (CW like)

✓ Classical hemodynamic response to a cuff occlusion
✓ No Crosstalk between haemoglobin and [oxCCO]
  ✓ Small changes in [oxCCO] compared to haemoglobin
  ✓ Different time evolution
Results – I Cuff Occlusion

Grand Average over all subjects and Detectors (n=24)

Method 1 (CW like)

Method 2 (Fitting)

✓ Classical hemodynamic response to a cuff occlusion
✓ No Crosstalk between haemoglobin and [oxCCO]
  ✓ Small changes in [oxCCO] compared to haemoglobin
  ✓ Different time evolution
✓ Good agreement between the 2 methods
Conclusions

- We have developed a Multi-wavelength Time Resolved NIRS system:
  - 2 sources
  - 4 detectors
  - Using 16 wavelength from 650 to 870 with a FWHM of 2-4 nm

- We have demonstrated the ability of this system to retrieve the changes in \([\text{Hb}], [\text{HbO}_2]\) and \([\text{oxCCO}]\) during a muscular cuff occlusion

- Our results are in good agreement with the literature

- Both methods are in good agreement
  - Promising to use the second one in order to investigate scattering effects and retrieve absolute concentrations.

- Currently working on functional brain activation detection
  - More challenging: Low changes in concentration and more time constraint
    - Optimising the SNR of the system
Acknowledgements
Thank you for your attention