Empirical Mode Decomposition of NIRS signals for assessment of cerebral and muscle thermoregulation

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Introduction

Near Infrared Spectroscopy (NIRS) allows the estimation of changes in haemoglobin in tissue by applying the Modified Beer Lambert Law. In order to study the effect of thermoregulation on peripheral and central location in this work NIRS signals from left brachioradialis and forehead of volunteers, obtained during a clod stress test were analysed. The analysis was carried out using Ensemble Empirical Mode Decomposition (EEMD).

Methods

After obtaining ethical approval of the Research Ethics Committee at City University eleven volunteers were subjected to cold stress testing. The investigation started with 2 minutes of baseline measurements at room temperature (24^{o}C), followed by ten minute period of cold stress (10^{o}C) and additional ten minutes re-warming at ambient temperature. The skin temperature was measured using a LDF probe (MoorVMS-LDF2, Moor Instruments).One of the two NIRS probe was positioned above the left brachioradialis and the other probe was placed above the left eyebrow avoiding the sinus cavity. The signals were sampled at 1 kHz.

For frequency domain analysis the signal can be split into six frequency regions of physiological interest. These regions includes venous component, cardiac cycle (0.5-2.0 Hz), respiratory component (HF) (0.15, 0.5 Hz), myogenic activity (Mf) (0.08-0.15), sympathetic activity (LF) (0.04-0.08 Hz) and endothelial activity (VLF) (0.003-0.04 Hz). From each NIRS probe four signals, changes in oxygenated and deoxygenated haemoglobin (ΔHbO2, ΔHHb), Tissue Oxygenation Index (TOI) and Normalised Total Haemoglobin Index (nTHI), were obtained. Each of these signal were decomposed into components using EMD. After the decomposition the components were assigned to one of the six frequency bands mentioned above and instantaneous power related to each band was obtained. The components were assigned into the frequency bands using the technique described in previous work [1].

A non-parametric test (Wilcoxon signed rank test) was used to compare the instantaneous power values at three different stages. The statistical analysis was carried out using SigmaStat (Systat Software Inc., USA). The significance level was set at $p < 0.05$ for all tests.

Results

An example of signal components obtained after EMD decomposition and assignment to relevant frequency band is shown in figure 1. From the decomposition presented in figure 1 components related to cardiac cycle, respiration and other low frequency components can be identified more easily compared to the original signal.

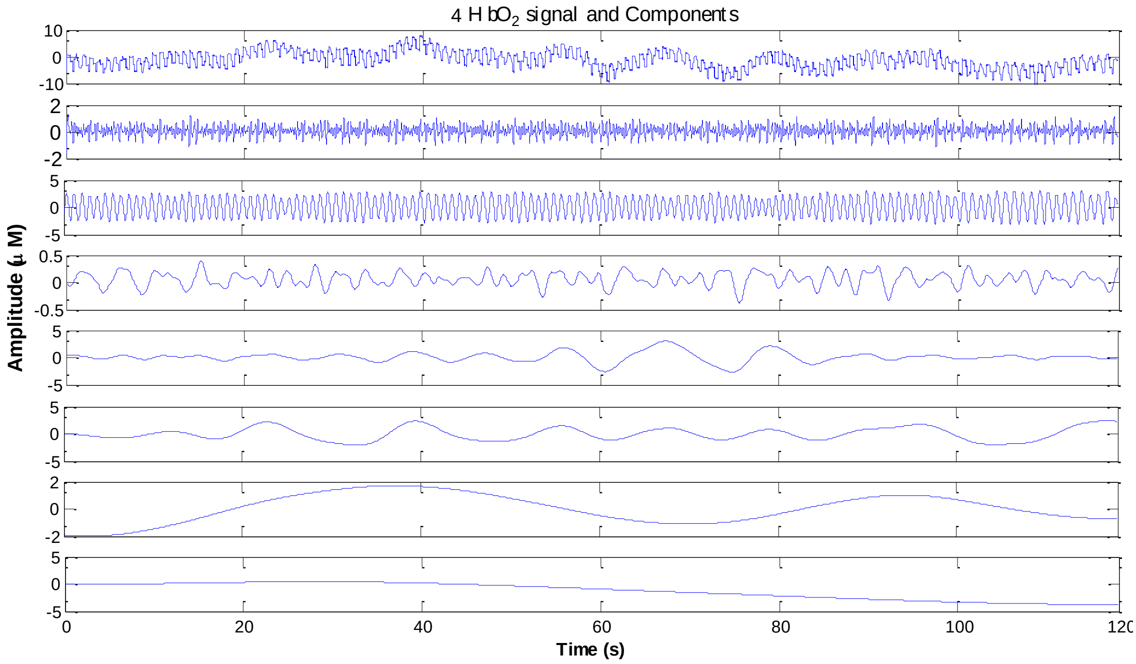

Figure 1: ΔHbO_2 signal (top plot) and resulting components obtained after EMD decomposition and assignment to particular frequency bands.

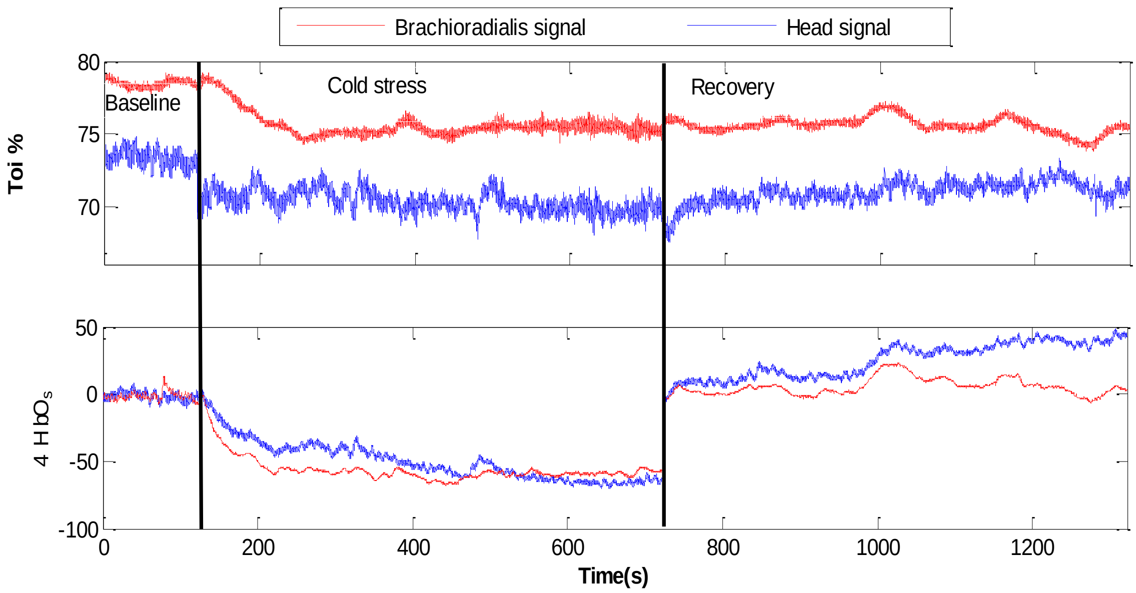

Figure 2: TOI and ΔHbO_2 signals from the two sensors in one of the volunteers included in this study.

The TOI and ΔHbO2 signals from the two locations in one of the volunteers are shown in figure 2.

The VLF region of TOI signal from the left brachioradialis sensor was the only parameter that showed significant changes ($p = 0.019$) during the study.

Discussion:

The decomposition of the signal into physiological meaningful component would allow the understanding of underlying phenomena which might be the cause of changes in haemodynamic. As shown in figure 2 ΔHbO_2 is showing changes at both sites but as this signal is coming from superficial layer the VLF power is not altered. The VLF power of TOI signal from brachioradialis has shown changes due the peripheral measuring site whereas, the same signal from the forehead is not changing due to the more central measuring site.

References

[1]K. Shafqat, S. Pal, S. Kumari and P. A. Kyriacou, 2011. EMD analysis of HRV data from patients undergoing local anaesthesia. Physiological Meas. 32(4):483-97.