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Electrical Impedance Measurement of Cerebral Haemodynamics

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Abstract: We demonstrate the utility of electrical impedance measurements for monitoring head haemodynamics by comparison to transcranial Doppler (TCD) recordings.

1 Introduction

Electrical Impedance Tomography (EIT) provides an alternative way to sense and image blood flow changes within the brain induced by the cerebral haemodynamics. As blood is electrically conductive, we propose using EIT to monitor the blood flow variations occuring during a Transient Hyperaemic Response Test (THRT). Our working hypothesis is that the flow of blood to the brain will increase its conductivity, and reduce the magnitude of the scalp potential measurements.

2 Methods and Results

2.1 Simulation

Our simulation results are based on a finite element head-shaped model having five tissues: the scalp, the skull, the cerebrospinal fluid, the grey matter and the white matter, with assumed conductivity values at 0.58, 0.008, 1.802, 0.2849 and 0.2556 S/m respectively. To emulate the perfusion of blood in the brain, we introduce an inhomogeneity residing at 2.6% of the grey matter tissue at a blood conductivity value of 0.646 S/m. We then apply 20 diametric-current patterns at an amplitude of 354μA for which we have computed forward solutions and simulated electrode potenials on the electrodes. At the electrode pairs positioned the closest to the inhomogeneity, our model yielded voltage measurements that were 22μV-34μV lower compared to the case without the inhomogeneity. As expected this computation is consistent with our hypothesis that an increase in the head's bulk conductivity will lower the impedance (voltage) measured at the electrodes. Tracing the electrode pair where this change is higher can provide some indication with respect to the location of the conductivity change.

2.2 Real Experiments

Twenty-one THRTs were performed on six subjects, approved by NHS RECs and MHRA. The left or right carotid artery was initially compressed for a period of 5s and then released while the blood flow velocity was measured via TCD, installed on both sides of the head. At the same time, EIT measurements were recorded at 100 frames per second using the fEITER system [1]. Twenty-nine electrode pair measurements spanning the scalp region were chosen for monitoring during the test (shown as the lines in fig. 2). In this context, the bulk conductivity change of the head between two consecutive time instants, $\delta\sigma_{bulk}$, is computed as

$$\delta\sigma_{bulk} = (J_{bulk}^T J_{bulk})^{-1} J_{bulk}^T \delta V \qquad (1)$$

where δV is the measurement difference, and J_{bulk} is one-parameter Jacobian.

The comparisons between the TCD and $\delta\sigma_{bulk}$ trends are shown in fig.1, and appear to be consistent to a large extend with the THRT hemodynamic scenario before and during occlusion (15 trials, 71.4%) as in fig. 1 (top). The $\delta\sigma_{bulk}$ trends after occlusion, however, are different for some tests. In four trials (19%) TCD and EIT predictions were still in synchrony but predicted inhomogeneities with opposite polarity, i.e. $\delta\sigma_{bulk}$ increased during occlusion as in fig. 1 (bottom), and in two trials (9.5%) we did not observe a significant change. The low or negative correlation cases might due to other – non THRT related cerebral activities, while the Rheoencephalographic signal was succesfully detected in all trials.

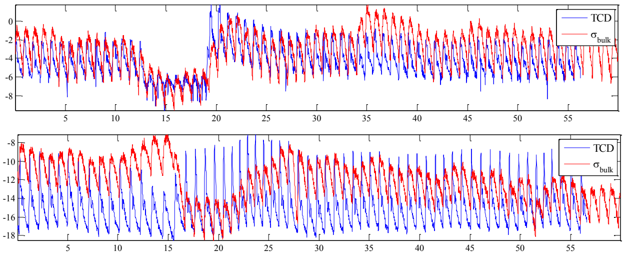

Figure 1: (top) A positive correlation example between $\delta\sigma_{bulk}$ and TCD trends and **(bottom)** a negative correlation example.

Additionally, an attempt can be made to localise the conductivity change, in terms of its proximity to the measuring electrodes, by monitoring the change in EIT measurements in real-time as shown in fig. 2. The decrease of conductivity on the occlusion side (left) can be seen in fig 2(a). When the occlusion ended, the conductivity at that side returns to its pre-occlusion value, fig 2(b).

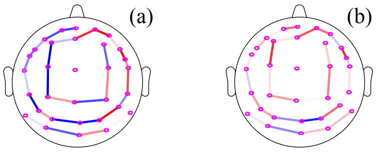

Figure 2: The real-time conductivity variation of fig. 1(a) – left occlusion THRT. Blue colour denotes decrease, and red increase. **(a)** The change during occlusion (17.81s); **(b)** the changes after releasing occlusion (21.20s).

3 Conclusions

Electrical measurement is able to monitor cerebral haemodynamics, and can also be used to roughly real-time visualize the conductivity changing on the scalp.

References

[1] McCann, H., et al., *33rd Annual Inter. Conf. of IEEE EMBS*, 2011.