Continuous Monitoring of Cerebral Blood Flow in Healthy Volunteers and Stroke Patients

Samuel van Bohemen[1*], Jeffrey Rogers[2], Jillian Clarke[2], Joaquin Valderrama[3,4], Philip Boughton[5,6,7], Andre Kyme[1,8]

***svan2111@uni.sydney.edu.au**

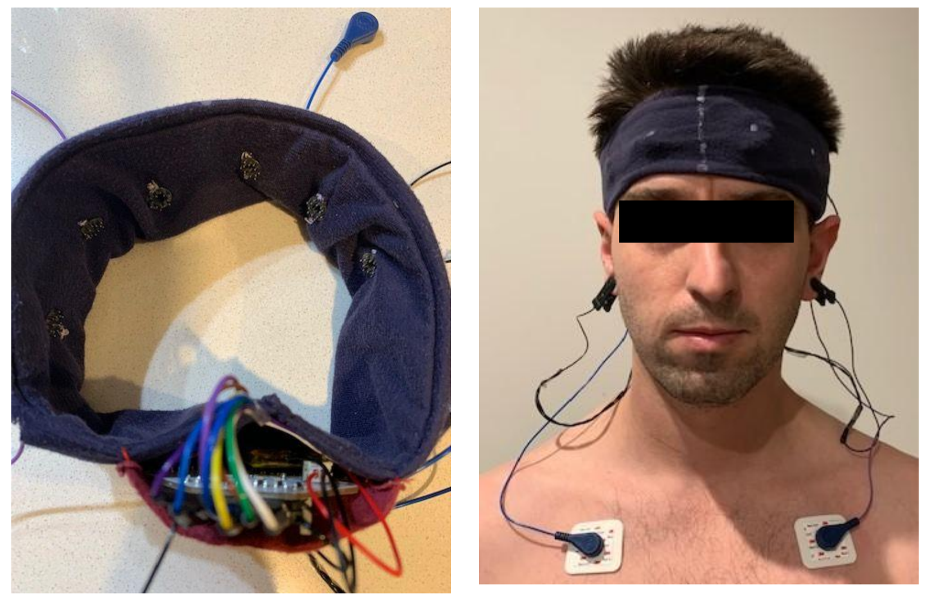
[1]School of Biomedical Engineering, University of Sydney, Australia
[2]School of Health Sciences, University of Sydney, Australia
[3]National Acoustic Laboratories, Sydney, Australia
[4]Linguistic Department, Macquarie University, Sydney, Australia
[5]Sydney Spine Institute, Australia
[6]School of Pharmacy, Faculty of Medicine and Health, University of Sydney, Australia
[7]Charles Perkins Centre, Faculty of Medicine and Health, University of Sydney, Australia
[8]Brain and Mind Centre, University of Sydney, Australia

Background

- Cerebral blood flow (CBF) is a key diagnostic parameter in acute ischemic stroke (AIS). Successful AIS treatment involves the restoration of CBF, for example via thrombolytic drugs like tissue plasminogen activator (tPA) [1].
- There is currently no device for the continuous monitoring of stroke patients in-between computed tomography (CT) scans.
- The heart generates the largest electrical signal in the body, the electrocardiogram (ECG). Blood is one of the most electrically conductive components of the body, hence providing a major pathway for electrical signal propagation. When blood flow increases, the electrical conductivity of the blood also increases [2].
- We hypothesise that increased CBF will increase conductivity of the blood and thus increase the amplitude of the ECG recorded across scalp electrodes, with reference to the same signal recorded across the chest.
- This method may be able to monitor changes in CBF.

Objective

- To investigate the feasibility of a new ECG-based method (Electrical Brain Perfusion Index (EBPi)) for monitoring changes CBF.
- EBPi was validated against changes in CBF detected using transcranial Doppler (TCD) ultrasound and compared with electroencephalography (EEG) relative alpha power (rAlpha).



EEG Headset

Methods

Experimental Protocol

- Hyperventilation induces a decrease in CBF and EEG rAlpha power [3].
- An EEG headset (OpenBCI 8-channel Cyton Board) with 4 scalp electrodes (Fp1, Fp2, F7, F8), 2 chest leads (LA and RA) and 2 ground/reference ear clip electrodes was fitted to the head of 6 participants.
- 3-minutes of baseline was followed by 3-minutes of hyperventilation (30 breaths per minute) which was followed by a 3-minute recovery period.
- 3 TCD measures of CBF velocity were captured from the right middle cerebral artery (rMCAv) immediately pre-task, post-task and following the recovery period.
- EEG/ECG data were streamed wirelessly to a laptop.

Data Processing

EBPi

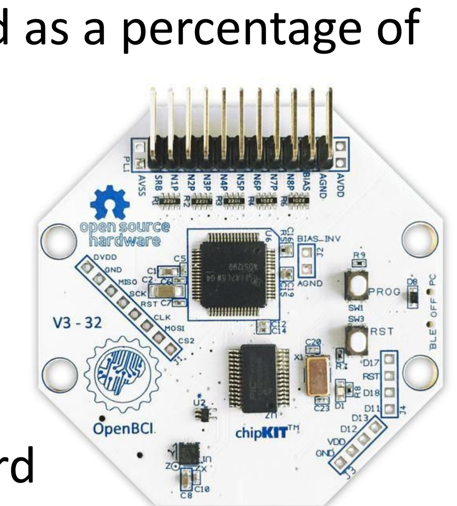
- EBPi was implemented by capturing ECG data at scalp electrodes by re-referencing each scalp electrode to chest electrode LA. ECG data were captured across the chest by re-referencing chest electrode RA to chest electrode LA.
- A 4th order bandpass filter (5-60Hz) was applied.
- The amplitude of ECG complexes at scalp electrodes was divided by the amplitude of the ECG complexes across the chest to generate EBPi. EBPi values were adjusted by baseline mean

TCD

- Repeat measure of TCD rMCAv captured at the 3 time points were averaged to produce mean rMCAv for each phase.

EEG

- A 4th order bandpass filter (0.5-30Hz) was applied.
- Epochs with amplitudes ±100 µV were excluded from analysis.
- 4-second epochs with 50% overlap were transformed using Fast Fourier Transform (FFT) to extract absolute power in all frequency bands
- rAlpha power (7.5-12.5Hz) was calculated as a percentage of total power (1.5-25Hz).



OpenBCI Cyton Board

Results

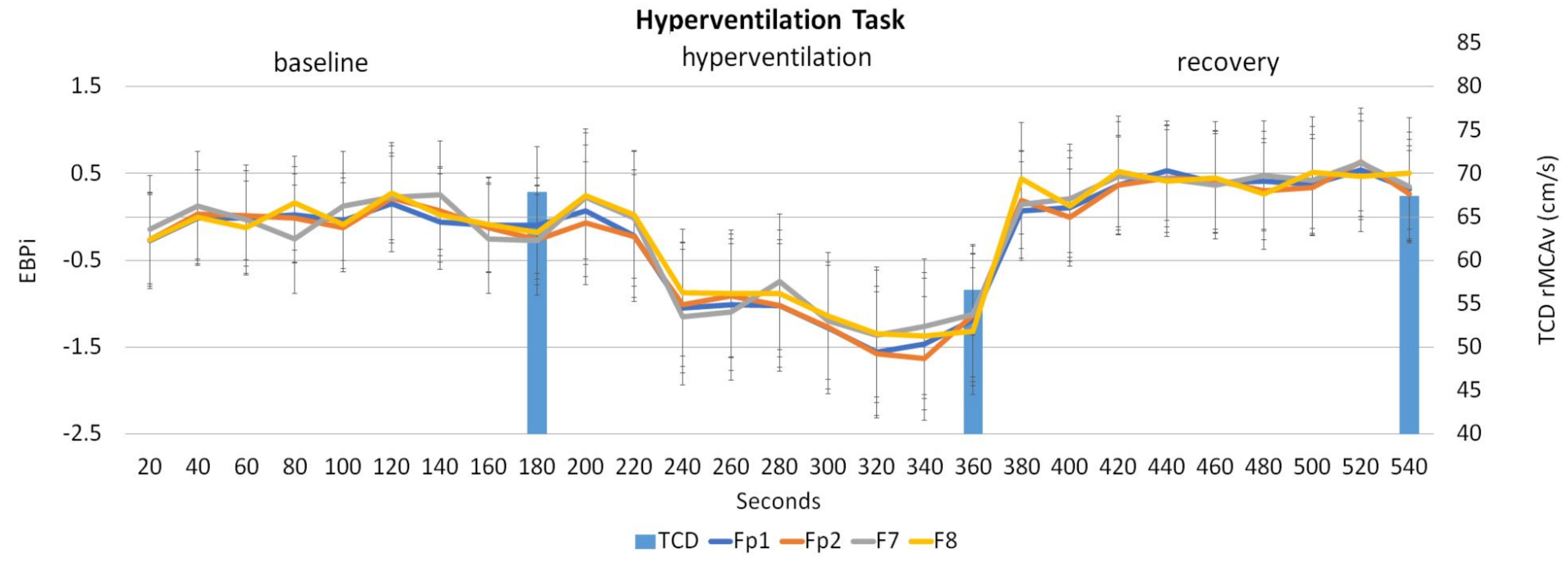


Figure 1. EBPi and TCD rMCAv) during a hyperventilation task (averaged across 6 participants). Line graphs represent EBPi recorded at scalp electrodes Fp1, Fp2, F7 and F8. Bar graphs represent mean TCD rMCAv. Red boxes represent the time windows during which TCD measures were obtained. Error bars = ±1 standard deviation.

Key Findings

- Both EBPi and TCD rMCAv decreased following hyperventilation and increased following the recovery period..
- There was a significant large positive correlation between mean EBPi and mean TCD rMCAv ($r=0.62$, $p<0.05$).
- There was a non-significant positive correlation between mean EBPi and mean EEG rAlpha ($r=0.15$, $p>0.05$)

Conclusion and Future Work

- EBPi showed a similar trend to TCD rMCAv and was significantly correlated to it.
- EBPi did not have a significant correlation with EEG rAlpha.
- EBPi may be able to monitor changes in CBF.
- These results indicate EBPi may also be able to measure CBF induced by other factors.
- We are currently testing other tasks such as breath holding, cognitive tasks and aerobic exercise.
- Since there is no device for the continuous monitoring of stroke patients in-between CT scans, this method could potentially fill this gap, thereby helping inform treatment and detect secondary stroke events.

Disclaimer

Samuel van Bohemen is the founder of Nuroflux Pty Ltd. Nuroflux Pty Ltd is the applicant of a filed provisional patent and PCT application (patent pending) for the described method of monitoring changes in CBF. Samuel van Bohemen, Philip Boughton and Andre Kyme are listed as inventors on the filed patent applications.

References

[1] S.-H. Lee, Stroke Revisited: Diagnosis and Treatment of Ischemic Stroke, Springer eBooks, 2017.

[2] A.E. Hoetink, T.J.C. Faes, K.R. Visser, and R.M. Heethaar, On the flow dependency of the electrical conductivity of blood. IEEE T Bio-Med Eng 51 (2004) 1251-1261.

[3] V. Kraaier, A.C. Vanhuffelen, and G.H. Wieneke, Changes in Quantitative EEG and Blood-Flow Velocity Due to Standardized Hyperventilation - a Model of Transient Ischemia in Young Human Subjects. Electroen Clin Neuro 70 (1988) 377-387.