Simultaneous Electroencephalography and Pseudo-Continuous Arterial Spin Labelling Measurements: Feasibility Study

Qingfei Luo[1], Chung-Ki Wong[1], Han Yuan[1], Vadim Zotev[1], Wen-Ming Luh[2], and Jerzy Bodurka[1,3]

[1]*Laureate Institute for Brain Research, Tulsa, OK, United States,* [2]*Cornell MRI Facility, Cornell University, Ithaca, NY, United States,* [3]*College of Engineering, Center for Biomedical Engineering, University of Oklahoma, Norman, OK, United States*

Introduction

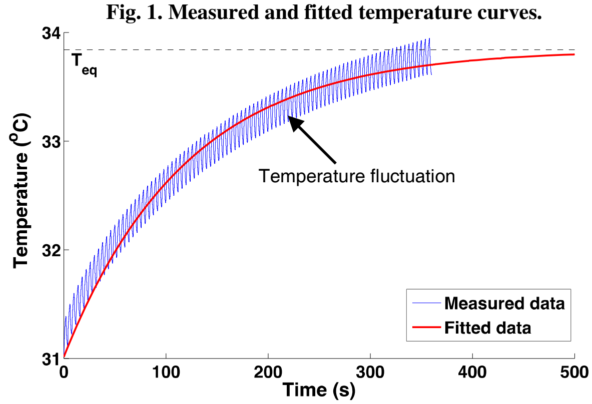
Pseudo-continuous arterial spin labeling (PCASL)[1] is a quantitative pulse sequence used for measuring cerebral blood flow (CBF). It is desirable to apply the PCASL sequence in EEG-fMRI studies to simultaneously detect the CBF-fMRI and EEG signals. However, compared to the gradient echo EPI sequence used in conventional EEG-fMRI studies, the PCASL has higher specific absorption rate (SAR) and will deposit more energy in the EEG electrodes, which may lead to electrode heating. This can result in the temperature increase of EEG electrodes, and it may potentially impose safety risks on human subjects. The aim of this study is to measure the temperature changes of EEG electrodes during concurrent EEG and PCASL acquisition, and evaluate if this heating effect can cause any safety hazards to the subjects.

Methods

EEG and ASL signals were concurrently acquired on three healthy human subjects at a 3.0 T MRI scanner (Discovery MR750; GE Healthcare Systems, Milwaukee, WI) and standard 8-channel receive only head coil. The EEG signal was recorded with a 32-channel MR-compatible EEG system (BrainAmp MR Plus; Brain Products GmbH, Munich, Germany). Eight axial ASL image slices covering the visual cortex were acquired (subject at rest with eyes open) using the PCASL sequence with the following parameters: labeling duration = 2.2 s, post-labeling delay = 1.5 s, TR = 4 s, TE = 12.4 ms, and flip angle = 90°. The parameters of labeling pulses were set as: Hanning-shaped RF with pulse duration of 375 μs, peak amplitude = 0.1 G, and inter-pulse interval = 1012 μs. The temperatures of EEG electrodes were recorded in real time using two MR-compatible temperature sensors (SKT100C; Biopac Systems, Goleta, CA) at 1 KHz sampling rate. The two sensors were placed on the left and right sides of the head and were adjacent to electrodes FC5 and FC6, respectively. The data acquisition lasted 6 min on each subject.

To analyze the heating effect induced by the PCASL sequence, the equilibrium temperature (T_{eq}) of the EEG electrode reached after long scan durations was calculated using the following equation[2]: $T(t) = T_{eq} + (T_0 - T_{eq})\cdot\exp(-t/\tau)$, where T(t) is the measured temperature at time t, T_0 is the measured temperature at t = 0 (i.e., start of scan), and τ is the time constant. T_{eq} was determined by fitting the measured data to this equation with two fit-parameters: T_{eq} and τ. To examine the fluctuation of the measured data relative to the fitted data, their differences (residual temperature signal) were calculated at all the time points. A Fourier transform was applied to the residual signal to obtain its power spectrum.

Fig. 1. Measured and fitted temperature curves.

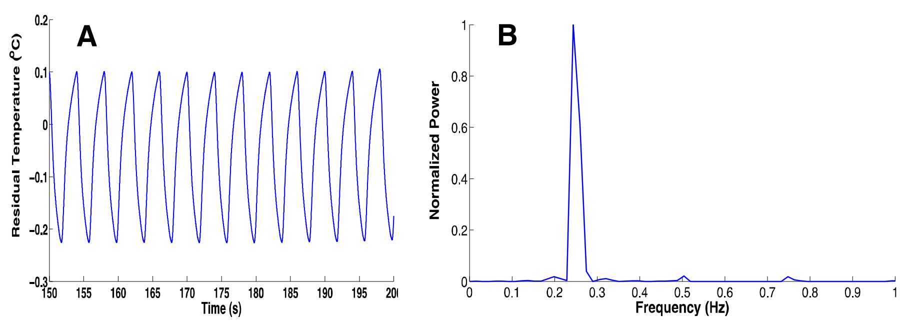


Results

Figure 1 shows the measured and fitted temperature curves at one EEG electrode in the typical subject. It was found that the electrode temperature increased immediately after the start of the PCASL scan. The rate of temperature change was reduced with the increase of scan duration. After the 6-min scan, the electrode temperature increased from 31.01 °C to 33.61 °C. The data fitting result indicates that after a long scan, the electrode temperature will reach the equilibrium temperature (T_{eq}) of 33.84 °C.

In addition, it is noted that the measured temperature data fluctuated around the fitted data (Fig. 1). Furthermore, this small temperature variation (standard deviation = 0.13°C) showed a periodical behavior (Fig. 2A) and its corresponding power spectrum (Fig. 2B) peaked at about 0.25 Hz, which is equal to that of the PCASL image acquisition (= 1/TR). This periodical fluctuation phenomenon could be induced by the variation of transmit RF power in each TR, i.e. the RF power difference between the labeling and image acquisition processes.

Fig. 2. (A) Time course and (B) power spectrum of residual temperature signal.



Another temperature sensor and the other subjects showed similar results to Figs. 1 and 2. The average T_{eq} over all the sensors and subjects was found to be 34.04 ± 0.38 °C (mean ± s.d). The average T_0 was 30.35± 0.67 °C, so a long PCASL will increase the electrode temperature by about 3.69°C. During the experiments, no safety hazard was observed on all the subjects.

Discussion and Conclusion

In this study, EEG electrode temperatures were measured and monitored in real-time during the simultaneous EEG and PCASL acquisition. The results showed that a long PCASL scan will increase the electrode temperature by approximately 3.69 °C and the electrode temperature will reach about 34.04 °C at equilibrium. Since this equilibrium temperature is far below the critical safety limit of 41°C[3], the concurrent EEG-PCASL acquisition would not result in significant safety risks on the subject. Furthermore, no other safety issues were found on all the subjects participated in this study. In conclusion, we showed the feasibility to safely conduct simultaneous EEG and PCASL measurements at 3 Tesla, and standard imaging hardware.

References

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