

Brain temperature and brain energy changes during tasks and light anesthesia: estimation with MRS

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Introduction: Physiological human brain temperature changes with some tasks were detected by MRS [1]. However, it is not clear whether the brain temperature rises or falls during brain activations [2, 3]. We have tried to monitor brain temperature changes during exercises and some other maneuvers. We found that the brain temperatures fall during light tasks such as hand grasp, tongue stimulation, and sedation.

Methods: ¹H-spectrum was used for the estimation of brain temperatures. MRS was performed at 3.0 T (GE Healthcare: Signa Excite HD 3T) on normal adult volunteers using PRESS without water suppression. Voxel size was 2cm x 2cm x 2cm. TR/TE were 3000ms/144ms. The spectrum was analyzed every 6 sec by our homebuilt soft. We calculated the brain temperature by using the chemical shift of water protons relative to acetyl protons of N-acetylaspartate as the temperature probe [4-6]. The brain temperature changes were measured under some exercises, tongue stimulation, and anesthesia (sedation level). The exercises were the lower leg flexion and hand grasp at the rate of about 1 Hz. A capsaicine solution (0.1 %, 20 μ L) was used for the stimulation of tongue. The sedation was induced by a single shot intra venous injection of midazolam. This sedation does not cause the loss of consciousness. The temperatures of esophagus/axilla and the heart rates were also measured simultaneously.

Results and Discussion: The standard deviation (SD) of our temperature measurements was about 0.1 $^{\circ}$ C for a human brain (Figure 1). Brain temperatures rose monotonously about 0.4 $^{\circ}$ C by 30 min during knee flexion and fell gradually after the end of exercise (Figure 1. left). The esophagus temperature also rose about 0.2 $^{\circ}$ C. The net temperature change of the brain tissue would be the subtraction between the changes of brain and esophagus, since the change of the temperature of blood flowing into the brain could be approximated by the change of esophagus temperature (representative of core body temperature). The net temperature change was estimated as 0.01 $^{\circ}$ C/min. This rise was found in relatively large regions of the brain. On the other hand, the brain temperature fell down during right hand grasp (Figure 1. right). This fall was found in the small region like the area detected by BOLD-fMRI. The brain temperature also fell on the stimulation of capsaicine. These rise and fall depends on the blood flow and the heat production of neurons. These falls indicate that the increase of the heat removal by blood is more than that of the heat production by neurons on brain activation. During sedation, the brain temperature fell 0.3 $^{\circ}$ C gradually. The esophagus temperature also fell and the net brain temperature change was about 0.005 $^{\circ}$ C/min. The blood flow changed little in this case. Therefore, the decrease of brain energy during sedation could be estimated as 0.2 W (estimated as a whole brain). Adult human brain consumes 20 W at rest. The energy difference of brain between arousal and sedation in our case was about 1 % of the energy that brain needs.

Conclusions: The dynamical human brain temperature changes during some tasks and sedation were estimated noninvasively using MRS. We could show that the brain temperature rises and falls depending on exercises, tongue stimulation, and sedation. The brain energy decrease during sedation was also estimated as 1 % of the energy that brain needs. The precise information of blood flow and activation/deactivation area are necessary, we could estimate the brain energy change quantitatively with the brain temperatures obtained by MRS.

References: [1] Y. Yoshioka, et al., Proc ISMRM 19: 1443 (2011). [2] D.A. Yablonskiy, et al., Proc Nat Acad Sci USA 97: 7603-7608 (2000). [3] A.M. Gorbach, et al., Ann Neurol 54: 297-309 (2003). [4] E.B. Cady et al., Magn Reson Med 33: 862-867 (1995). [5] R.J.T. Corbett et al., J Neurochem 64: 1224-1230 (1995). [6] R.J.T. Corbett et al., NeuroReport 9: 2722-2725 (1998).

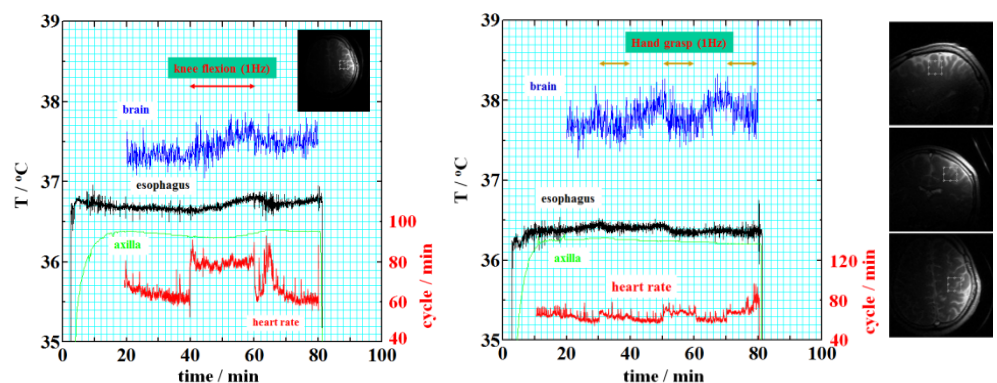


Figure 1. Brain temperature changes during light exercises. Left: right knee flexion of 1 Hz. Right: right hand grasp of 1Hz. Blue line: brain temperature, black line: esophagus temperature, green line: axilla temperature, red line: heart rate.