The intraoral stimulus increases the regional brain temperature in the insular cortex of rats: a proton MR spectroscopy study

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[Purpose]

Invasion of the brain such as surgery, tumor, and nerve damage induce inflammatory responses including heat production at the damaged area. The changes in the regional brain temperature (rBT) mean elicitation of some physiological responses. Thus, non-invasive measurement of the rBT is useful for clinical practice. It is known that the magnetic resonance frequency of water protons depends on temperature, and it changes with a coefficient of about −0.01 ppm/°C[1)]. However, the correlation between the rBTs and changes in temperature calculated by a proton magnetic resonance spectroscopy (MRS) remains unclear. Therefore, we verified a proton MRS as a non-invasive measurement method of rBTs. In Experiment 1, we simultaneously recorded rBTs and electrophysiological neuronal activities in the insular cortex (IC)[2)] of rats before, during, and after somatosensory stimuli to the tongue. Secondly, we measured rBTs in the IC using MRS as the noninvasive measurement in Experiment 2. All experiments were performed in accordance with the guidelines of the animal ethics committees of our institutions for the care and use of laboratory animals.

[Methods]

Experiment 1: The recordings of electrophysiological signals and temperatures

Five male Wistar rats served as subjects. All rats were anesthetized with urethan and fixed in a stereotaxic instrument. We recorded the neuronal activities and temperature. Oral stimuli were electrical stimulations, 10% ethanol, and 0.1% capsaicin dissolved in 10% ethanol. The electrode was made from two 80 μm stainless steel wires insulated with polyurethane except at the cut end. The electrode was obliquely inserted into the contralateral IC at an angle of 45°. Neuronal activities were amplified with a conventional method and monitored with a computer-aided data-acquisition and analysis system. In the temperature recording, the thermo-couples, bonded with the fine-wire electrode 0.5 mm at backwards, were inserted into the IC.

Experiment 2: The measurements of the rBTs to the intraoral stimulus in the IC by MRS

Five male Wistar rats served as subjects. All rats were maintained in an anesthetized state by breathing 1.2% isoflurane and fixed in the probe of the MR apparatus with a plastic holder. MRS was performed with an ultrahigh resolution, 11.7-T MRI scanner with a point resolved spectroscopy for a proton (TE=80 ms, TR=4000 ms, ROI=4x4x4 mm^3, NEX=128) by every 10 mins, from 30 min before the stimulation. We used the same stimulation as Experiment 1. We compared the peak of chemical shift between water and metabolites (NAA, Cho, and Cr), and calculated the changes in temperature (℃) after the measurement of MRS.

[Results]

Figure 1 shows rBTs to each stimulus in the IC, and the histological reconstructions of the recording site in Experiment 1. We divided all rBT data into two groups, "Responsive" and "No-responsive" groups. Figure 1A shows that the changes in the rBT (ΔT) in the IC in the Responsive group (0.013 ± 0.002℃) was significantly higher than those in the No-responsive group (0.003±0.002℃). We also found that the 10% ethanol contained 0.1% capsaicin induced significantly larger ΔT (0.080 ±0.02℃) in the IC than the 10% ethanol (0.014 ±0.003℃) (Figure 2). In Experiment 2, the difference between the peak of water and the peak of the chemical shift for NAA, Cho and Cr reduced by the 0.1% capsaicin. But we observed no changed by the 10% ethanol. For converting the difference of chemical shift into temperature (℃), the rBT was elevated in comparison with before 0.1% capsaicin stimulation (0.05-0.1℃).

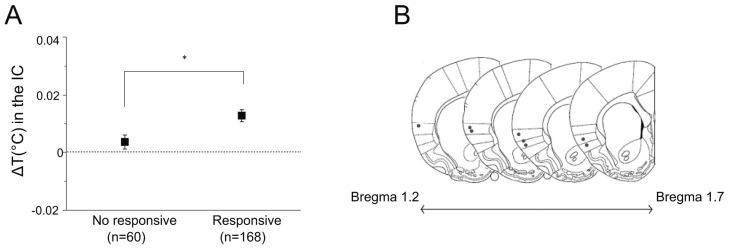

Fig. 1. A: The rBT (ΔT) in the IC of 2 types (Responsive and No responsive) of neuronal responses to electrical stimuli. B: Recording sites in the standard atlas sections of the IC of rat (Paxinos and Watson 1998). Symbols indicate sites that evoked excitatory responses.

[Discussion & Conclusion]

The main finding of the present study is that the rBTs and neuronal activities simultaneously increase just after the intraoral stimulation. The IC is involved in the somatic sensation in the oral cavity and tongue, and the cognition of taste quality and intensity[2, 3)]. In addition, we showed that the rBT increased by the capsaicin stimulation using MRS. Because capsaicin is to be a strong sensory stimulus, it is likely that the observed changes in the MRS measurement are correlated with the results of the recordings of the rBT and neuronal activities. Therefore, we conclude that the increases in the rBTs and neuronal activities in the IC are simultaneously induced by the intraoral stimulation. The intraoral stimulus-induced alterations in peak values of a chemical shift shown by MRS measurement indicate the changes in rBTs.

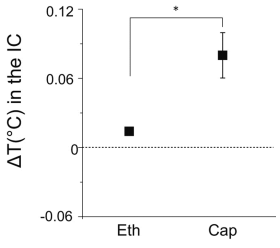

Fig. 2. The rBT (ΔT) in the IC by Eth (10% ethanol) and Cap (0.1% capsaicin).
* $p < 0.05$.

[References]

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