

DWI-Thermometry Study on Differences by Imaging Conditions of LV Temperature Measurements and Its Temperature Changes by Tympanic Temperature

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Target audience

Brain temperature researchers

Purpose

Regarding the measurement of brain temperature, various methods using magnetic resonance (MR) imaging¹⁻⁴ have been proposed in the past. Among these MR methods, the most clinically applicable approach may be the DWI-thermometry method, which utilizes post-processed data from diffusion-weighted images (DWI).⁵⁻⁷ This DWI-based method, however, is relatively recent and insufficient yet in its analysis. Therefore, further detail study and evaluation will be needed. The purpose of this study is to investigate the stability of this technique in brain temperature measurement, to see how its method would be affected under different imaging conditions (e.g. slice thickness), or to investigate the relations between the measured brain temperature with body temperature.

Methods

Data acquisition: [Study 1] 10 healthy adults (6 men and 4 women), ranging in age from 25 to 32 (mean \pm SD 27 \pm 0.2), were enrolled for this study. For DWI, we used single-shot echo-planar images (EPI) with a b value of 1000 sec/mm², and also used 3mm and 5mm for slice thickness, in addition, with motion-probing gradient (MPG) in 3, 6, 15 and 32 orientations. The MR imaging sequence was performed three times consecutively under the same conditions. [Study 2] 13 healthy adults (8 men and 5 women), ranging in age from 25 to 32 (mean \pm SD 26.9 \pm 1.7), were enrolled. The subjects underwent DWI with a slice thickness of 3mm and the MPG set in 15 orientations. This imaging protocol was repeated under the same conditions in the following week.

All of the MR images were obtained using a 1.5 T system (Gyrosan Intera; Philips Medical Systems, Best, The Netherlands). The bilateral tympanic temperatures of all the subjects were also measured before MR scanning.

Temperature calculation: Temperature was calculated using the following equation: $T (^{\circ}\text{C}) = 2256.74 / \ln(4.39221 / D) - 273.15$,³ where D [mm²/s] is the diffusion coefficient. The mean temperature was calculated by the histogram curve-fitting method. The lateral ventricle, as region of interest, was manually segmented on the b0 image in this study.

Results

[Study 1] There was no significant difference between the measured brain temperatures of the three consecutive scans ($P = 0.25$). There was also no distinct difference in temperature among the different MPGs ($P = 0.15$). However, some significant difference in the measured temperature was observed between different slice thicknesses ($P < 0.0001$, Fig. 1). The range for the slice thickness, defined by subtracting the minimum value from the maximum one, was consequently smaller for slice thickness of 3mm than that of 5mm ($P < 0.0021$, Fig. 2). [Study 2] There was considerably a positive correlation between the tympanic temperature and the measured lateral ventricular (LV) temperature in temperature changes ($P < 0.021$, Fig. 3).

Discussion

Applying different slice thicknesses in diffusion-weighted LV temperature measurement might lead to different results. This change is probably caused by the partial volume effect, because the 5mm thickness slices would incorporate more brain parenchyma than that of the 3mm thickness slices. Since the brain parenchyma exhibits lower diffusivity than cerebrospinal fluid, thus it is understandable that the additional brain parenchyma covered within the 5mm thickness slices will result in lower calculated LV temperatures. We know, in brain temperature homeostasis, that it is maintained by both heat production and heat removal. It is thought that, when the tympanic temperature (which corresponds to the body temperature) rises, the overall temperature of the blood will also rise. As a result, the radiator function of the cerebral blood flow would decrease, and thus bring to the elevation of brain temperature.

Conclusion

LV temperature measurement was carried out successfully using DWI-thermometry. Slice thickness was found to have significant effects on the calculation of LV temperature, and furthermore, thinner slice thickness was considered to produce better results than thicker slices. Also we confirmed that LV temperature would change along with tympanic temperature.

References

- [1] Le Bihan D, Delannoy J, Levin RL. Temperature mapping with MR imaging of molecular diffusion: application to hyperthermia. *Radiology* 1989;171(3): 853-857.
- [2] Corbett RJ, Purdy PD, Laptook AR, et al. Noninvasive measurement of brain temperature after stroke. *AJNR Am J Neuroradiol.* 1999;20(10):1851-1857.
- [3] Kozak LR, Bango M, Szabo M, et al. Using diffusion MRI for measuring the temperature of cerebrospinal fluid within the lateral ventricles. *Acta Paediatr.* 2010;99(2): 237-243.
- [4] Sakai K, Yamada K, Sugimoto N. Calculation methods for ventricular diffusion-weighted imaging thermometry: phantom and volunteer studies. *NMR Biomed.* 2012;25(2):340-346.
- [5] Yamada K, Sakai K, Akazawa K, et al. Moyamoya patients exhibit higher brain temperatures than normal controls. *Neuroreport.* 2010;21(13):851-855.
- [6] Sakai K, Yamada K, Mori S, et al. Age-dependent brain temperature decline assessed by diffusion-weighted imaging thermometry. *NMR Biomed.* 2011;24(9):1063-1067.
- [7] Tazoe J, Kei Yamada, Koji Sakai, et al. Brain core temperature of mild head trauma patients as assessed by DWI. *ISMRM.* 2012; 3708

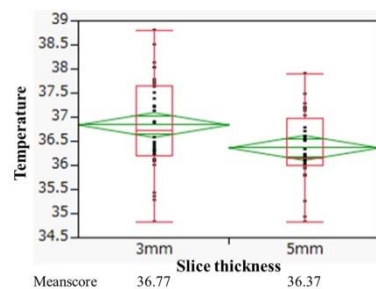


Figure 1. There was significant difference between different slice thicknesses ($P < 0.0001$).

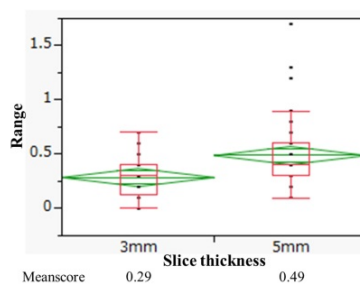


Figure 2. The range for the slice thickness was significantly smaller for 3mm slice thickness than that of 5mm ($P < 0.0021$).

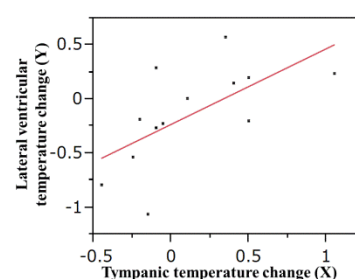


Figure 3. There was a significant positive correlation between the tympanic temperature and lateral ventricular temperature in temperature change ($P < 0.021$).