

DWI based thermometry: Analysis method and its applications

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INTRODUCTION

There are a few different ways of assessing the brain temperature. Direct measurements have been done in those who had cranial surgery [1, 2]. Noninvasive methods using magnetic resonance (MR) imaging techniques have been also proposed [3, 4, 5, 6, 7]. Among these MR methods, the most clinically applicable one could be the post processing of the diffusion-weighted image (DWI) [6, 7]. Although only applicable to the non-restricted water, e.g. cerebrospinal fluid (CSF), it is thought to be potentially useful in assessing the thermal pathophysiology of the brain in both patients [8] and healthy subjects [7]. Nevertheless, this DWI based method requires predefined threshold values to calculate mean temperature, which causes biased results [6]. The purpose of this study was to develop new calculation method, which does not require user depending threshold and uses the curve fitted histogram of temperature distribution in CSF.

METHODS

Subjects: The DWI data of 23 healthy subjects (aged 26-75 years, mean 50.13 years \pm 19.1 SD) were used for calculation method developing. The study was approved by the Ethics Committee of Kyoto Prefectural University of Medicine.

Data acquisition: All MR examinations were performed on a 1.5T whole body imager (Philips Medical Systems, Best, The Netherlands). The diffusion-weighted imaging (DWI) was done with an image acquisition time of approximately 3 minutes. A single-shot echo-planar imaging technique was used for DWI (TR/excitation time = 6000/88 ms) with a b-value of 1000 s/mm² and image averaging of 2 times. Motion sensitizing gradients were applied to 15 directions. A total of 42 sections were obtained with a thickness of 3 mm without intersection gaps. The other conventional MR images analyzed in this study include fluid level-attenuated inversion recovery (FLAIR) images (delay time 2200 ms; TR 8000 ms; TE 100 ms) and time-of-flight MR angiography (TR 30 ms; TE 2.3 ms).

Temperature calculation: The temperature was calculated by the following equation; $T(^{\circ}\text{C}) = 2256.74/\ln(4.39221/D) - 273.15$ [9], where D is the diffusion coefficient. The mean ventricular temperature was calculated by four methods [10]: two thresholding methods (A and B in Figure 1) and two histogram curve-fitting methods (C and D in Figure 1). The mean temperature in the method A, B, and D was calculated using T_{low} and T_{high} as the lower and higher thresholds. In method C, the mode value of fit-curve was employed as the mean temperature. As a reference, we used the temperature measured at the tympanic membrane, which is known to be approximately 1°C lower than the brain temperature [11].

RESULTS AND DISCUSSION

Figure 2 shows the comparisons of the four DWI thermometry calculation methods. Because the gold standard of the core brain temperature was assumed to be approximately 1°C higher than the measured tympanic temperature, methods C and D appeared to yield temperatures that were closer to reality. The SD, on the other hand, was wider for methods C and D than for methods A and B. More important could be the fact that the curve-fitting method does not involve arbitrary determination of the threshold and thus could be more objective.

CONCLUSION

LV temperature in healthy subjects was measured by DWI-thermometry with four different calculation methods. The histogram curve-fitting methods seemed to yield more appropriate temperatures, using tympanic temperature as a reference. However, these methods had wider SD than the thresholding methods, which may have to be overcome by a further improvement to the calculation method.

References

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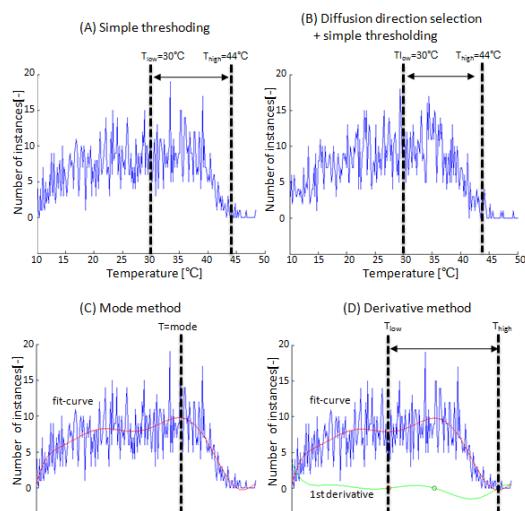


Figure 1: The evaluated ventricular temperature calculation methods. (A) simple thresholding, (B) diffusion direction selection + simple thresholding, (C) histogram curve fitting (mode method), and (D) histogram curve fitting + 1st derivative (derivative method). T_{low} and T_{high} indicate the lower and higher thresholds for the ventricular temperature calculation.

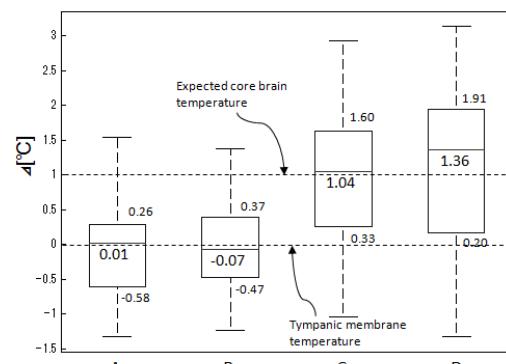


Figure 2: The comparisons of the four DWI thermometry calculation methods. Deep brain temperature is anticipated to be above $\Delta=1^{\circ}\text{C}$ indicated by the upper dashed horizontal line.