

Movement artifacts in monitoring the brain temperature during induction of mild hypothermia

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Introduction

Brain temperature reduction was recognized as a promising treatment after hypoxia-ischemia caused by cardiac arrest, stroke, trauma, etc (1). One of the brain cooling mechanisms is heat loss through the upper airways (2). Verifying the brain-cooling effectiveness non-invasive is, however, challenging. To our knowledge, solely brain heating experiments (focused ultrasound surgery) have been reported. In these experiments, the phase-difference (3) methods were used for monitoring the large temperature changes (15 - 20 °C) in small and well defined regions ($\Phi < 10$ mm). The whole experiment did not extend ~1 min. Requirements for measurement of the brain temperature changes during cooling are opposite. These experiments require monitoring a small temperature change (< 3 °C), in large volumes and during a long period of time (~60 min). Purpose of this study was to compare spectroscopic imaging (MRSI) with high spatial and reduced spectral resolution (4) and phase-difference technique (3) used for monitoring the brain temperature changes during cooling and to study their sensitivity to the random and systematic movement artifacts.

Materials and Methods

Brain cooling of ten healthy volunteers (age, 21-62 years) was performed through both nasal cavities using saline solution cooled balloon catheters (2). Cooling medium (~20 °C) at a flow rate of 100 ml/min induced a brain temperature reduction (1 - 3 °C) in ca 15 minutes. All measurements were performed with a 1.5 T MR scanner (Intera, Philips). The volunteer's head was supported by foam pads to minimize movement. 2D MRSI sequence with high spatial resolution was based on a 2D rf spoiled gradient echo (4). The spectral information was encoded by incrementing the echo time of the subsequent eight image records. Spectral BW and resolution was 10 ppm and 1.25 ppm, resp. Resolution in plane was 1x2 mm. The slice thickness was 5 mm. Reconstructed voxel size was 1x1x5 mm³. Net measurement time was 41 sec. Relative brain temperatures were computed from the changes of the water spectral lines positions in each voxel. Phase maps used in phase-difference method were computed from the first image record ($TE_1 = 6$ ms) of the MRSI sequence. Temperature changes were evaluated using brain water chemical shift coefficient -0.019 ppm/°C (4). Relative temperatures were averaged from volume of interests (VOI) V1-V5 in transversal and sagittal slices (Fig. 1). The experiment began with four baseline records. Brain cooling was then started ($t = 0$ min). Measurement of the transversal and sagittal slice started at each odd and even minute, resp. Relative baseline temperature was computed by averaging the first four measurements ($t \leq 0$ minutes) and set to 0 °C.

Results

Representative brain temperatures changes during cooling are shown in Fig. 2a, b and 3. Figures 2c, d illustrate the correlation between MRSI and phase-difference measurements shown in Fig. 2a, b. While very good and significant correlation between methods have been found in occipital (V1) and parietal (V2) lobe (Fig. 2c), low and insignificant correlation was found in the frontal lobe (V3) (Fig. 2d). Random and reversible rotation of the head (Fig. 1) was the main reason for dispersion of the relative temperatures. These artifacts are most pronounced in the phase-difference results shown in Fig. 2b and Fig. 3b. Systematic and irreversible artifacts, the stepwise reduction of the temperature at the time $t \geq 30$ minutes, can be seen on MRSI results shown in Fig. 3. These artifacts were not so clearly seen in the phase-difference measurements. The stepwise artifact originated from the involuntary systematic rotation of the head (Fig. 1). Note that volunteers were disturbed by blood sampling from the forearm at the time $t = 30$ minutes. The stepwise change of the temperatures was observed exclusively in the sagittal slices and was common for all 10 volunteers. Measurements of the temperature changes in transversal slices, especially in the parietal and occipital lobes were more robust to the movement artifacts than in the sagittal planes.

Discussion

Both, the phase-difference and MRSI method were sensitive to the slight involuntary rotation of the head. It was extremely difficult to achieve stability in subpixel level during the experiment (~60 minutes) in spite of immobilization by foam pads. Two main rotations of the head were observed: (i) the left-right (Fig. 1a) and (ii) feet-head (Fig. 1b). While foam pads were able to restrict the left-right rotation, they were ineffective to hinder rotation in the feet-head direction. The regions close to the rotation centers in parietal and occipital lobe were therefore lower than in frontal lobe.

Conclusions

Good agreement was found between relative temperatures measured by MRSI and phase-difference techniques in the most stable parietal and occipital lobe. Measurements in the transversal slices were more robust to the movement artifacts than those in sagittal planes.

References

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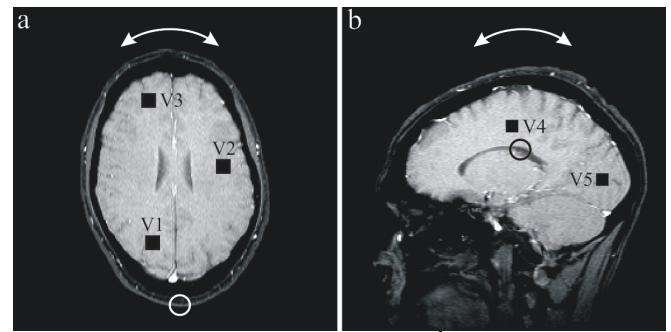


Fig. 1: VOIs positions (10x10 pixels, 0.5 cm³). Arrows show rotation directions. Positions of the rotation centers are outlined by circles.

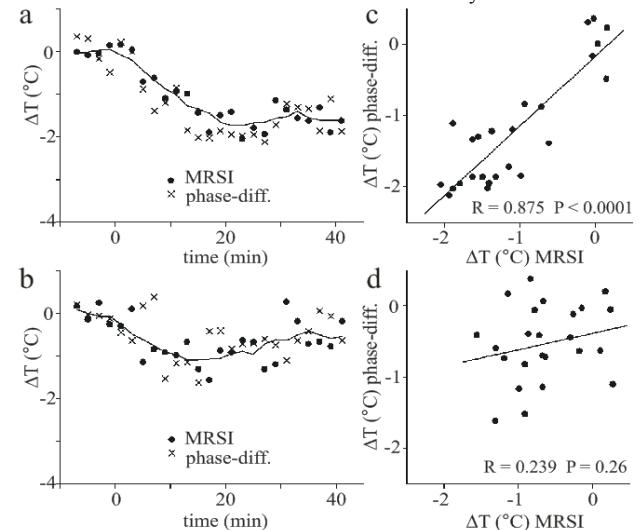


Fig. 2: Relative brain temperatures during cooling in the transversal slice. Temperatures were averaged from VOI (a) V1 and (b) V3. Full lines represent smoothing of MRSI temperatures. Correlation of the relative temperatures measured by MRSI and phase-difference techniques in VOIs (c) V1, and (d) V3.

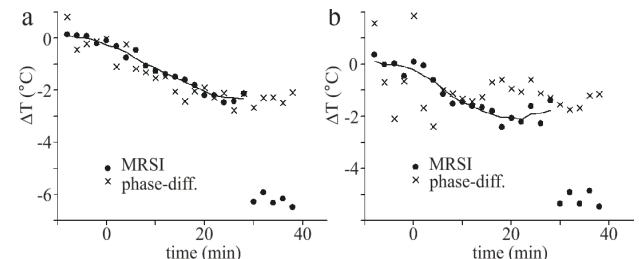


Fig. 3: Relative brain temperatures during cooling in the sagittal slice. Temperatures were averaged from VOI (a) V4, (b) V5. Full lines represent smoothing of MRSI temperatures.