# Magnetic Resonance Spectroscopy based Temperature Calibration and in-vivo Brain Temperature Measurement of Traumatic Brain Injury Rats at 7 Tesla

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**INTRODUCTION:** Magnetic resonance spectroscopy (MRS), based on non-invasive, *in-vivo* temperature measurement of brain is currently one of the most accurate ways of mapping the region specific temperature distribution. [1, 2]. Such a temperature measurement relies on the chemical shift separation between water (sensitive to temperature) and N-Acetyl Aspartate (NAA). Hence, it is necessary to calibrate/derive the relationship between the chemical shift of the water with reference to temperature, by using the brain metabolite phantom for the given field strength of the magnet. Traumatic Brain Injuries (TBI) cause raised body and brain temperature in association with inflammation and other neuroprotective mechanism [3]. Monitoring the region specific brain temperature *invivo* helps in predicting the prognosis of the treatment in the TBI subjects.

**METHODS:** *Temperature calibration using phantom:* A two-compartment glass phantom (Fig.1), which fits inside a 4-channel phased array coil (RAPID Biomedical, Germany) was designed and fabricated for the study [4]. Phosphate buffer solution with 61.25 mM NAA, 39.25 mM Creatine & 8.5 mM Choline (all the metabolites concentration were approximately 5 times of the normal rat brain concentrations [5]) in 100ml,with pH 7.2 was used to fill the inner chamber of the phantom. Temperature controlled water was circulated in the outer compartment to maintain the metabolites at different temperatures. A high precision temperature controlled water circulator was used to circulate water at a constant rate in the phantom. An optical temperature probe was used to measure the temperature of the metabolites. The MRS was performed on the phantom at different temperatures (30 ºC to 40 ºC at ~1ºC intervals) using a 7T Bruker Clinscan MRI/MRS scanner. A voxel of 7 × 7 × 7 $mm^3$ size was placed at the centre of the inner compartment. A Position Resolved Spectroscopy (PRESS) based MRS spectrum with (16 averages) and without (2 averages) water suppression was acquired to compute the shift between the NAA and the water peak at every temperature. The relationship between the chemical shifts of NAA, Water (ppm) and temperature was derived (Fig.2) using the experimental values (Eqn.1).

$$T = -103.75 * (\text{NAA - Water spectral shift in ppm}) + 314.7, \qquad (1)$$

*In-vivo data collection:* PRESS sequence was utilized to collect *in-vivo* data at multiple time points (Baseline (BL), Day-1, 3 & 5 after the injury) from the hippocampus of the traumatic brain injured rats. The MRS data was collected using a short TE/TR/TA=13 ms/4 s/~8 mins, voxel size of 3.5 × 2.0 × 3.5 $mm^3$, with (128 averages) and without (8 averages) water suppression. Eddy current compensation and scaling were performed using the water-unsuppressed spectrum for the calculation of spectral shift between the NAA and water peaks at every time point. The hippocampus temperature was calculated by substituting the values of spectral shift in the above equation for each time point (Fig. 3. Right).

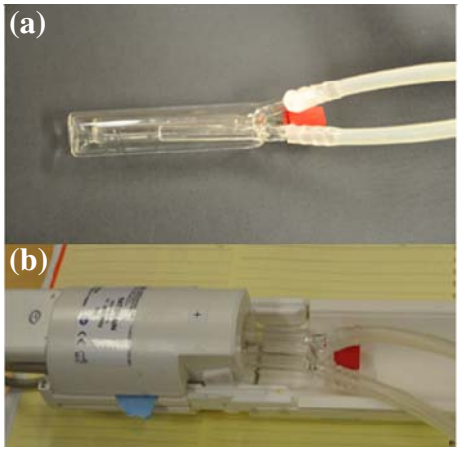


**Figure 1. (a)** Water circulating Phantom used for temperature calibration, **(b)** Phantom housed inside 4 -channel phased array rat brain coil.

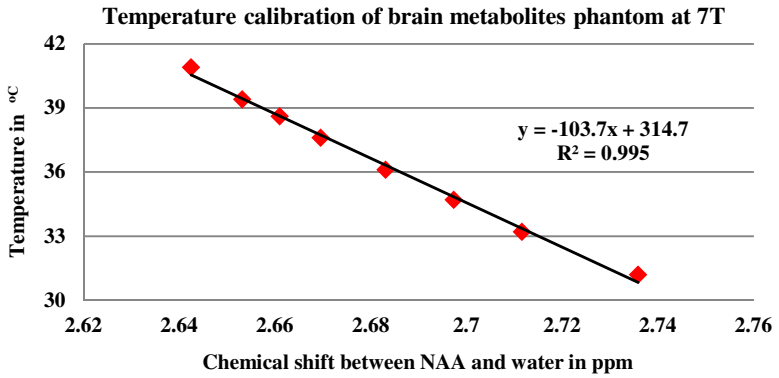


**Figure 2.** Temperature Calibration curve to map chemical shift to actual temperature in ºC.

| | Rat 1 | Rat 2 | Rat 3 | Rat 4 | Rat 5 | Average |
|---|---|---|---|---|---|---|
| **BL** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | |
| **Day 1** | 1.69 | 2.07 | 0.16 | 3.19 | 1.03 | 1.63 |
| **Day 3** | 0.95 | 3.63 | 1.70 | 4.96 | 1.99 | 2.65 |
| **Day5** | 2.44 | 3.78 | 1.11 | 3.26 | 1.33 | 2.38 |

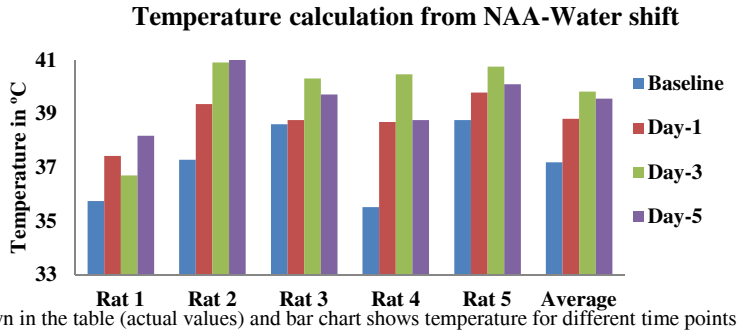


**Figure 3.** Temperature changes after the injury to hippocampus is shown in the table (actual values) and bar chart shows temperature for different time points

**RESULTS and DISCUSSIONS:** The NAA-Water chemical shift separation was linearly proportional to temperature. Our brain temperature calibration was in agreement with earlier work of Zhu et al [2]. Figure 2 shows the temperature values obtained using the calibration relation (Eqn. 1) from the MRS of the TBI rats. There is an average increase of 2.6 ºC and 2.4 ºC in temperature at the hippocampus on Day-3 and 5 respectively with respect to the baseline (Fig. 3). The brain temperature peaked on Day-3 and decreased during the recovery phase. The chemical shift of NAA in the brain was at 2.01 ppm in both normal and TBI rats.

**CONCLUSION:** We have calibrated the brain temperature on a 7T MRI/MRS scanner using a custom designed phantom. The water chemical shift showed a linear dependence on temperature in the phantom calibration. Increased brain temperature was observed in the TBI rats until Day-3 and it decreased subsequently. The MRS based non-invasive brain temperature measurement is useful and accurate, and can be easily translated to clinical settings [6].

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