Detection of Inhomogeneous B_1 Deposition *via* PARACEST Thermometry

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Introduction

In the last decade, MRI technology has been demonstrated in human at much higher fields (B_0) in pursuit of better signal-to-noise ratios (SNR) and improved image resolution. As B_0 is increased, the wavelength of the electromagnetic field becomes more comparable to the size of tissue structures; thus leading to excessive heating of the body as a direct consequence of higher electromagnetic energy deposition,[1] which is usually expressed in terms of the specific absorption rate (SAR). It has been postulated that temperature calculations and measurements within the body might be a more suitable guideline than SAR in assessing the level of health associated risks due to electromagnetic field interactions with living tissue.[2] So far, many numerical approaches have been reported.[3] However, it would be even better if the energy deposition could be measured experimentally in a non-invasive manner.

The water proton resonance frequency (PRF) method is the most widely used MRI thermometric technique.[4] This method is, however, sensitive to motion effect and B_0 in-homogeneity because of its small temperature dependency (-0.01 ppm/°C). Alternative approaches, for example, by using exogenous temperature probes of either paramagnetic contrast agents[5, 6] or shift reagents,[7, 8] have been reported to increase the temperature responses. Very recently, we have reported an even more responsive MRI thermometry based on paramagnetic chemical exchange saturation transfer (PARACEST) mechanism.[9] Presented here is a further application of PARACEST thermometry in evaluation of B_1 deposition *in vitro*.

Results and Discussion

PARACEST thermometry is based on the temperature dependency of highly hyperfine-shifted position (δ, in ppm) of the exchanging site on the PARACEST agent; for example, the lanthanide bound water protons (Ln^{3+}-H_2O). Their ^1H chemical shifts vary linearly over 20–50°C according to $\delta_{PPM} = 6.9*T - 944.7$ and $\delta_{PPM} = -0.4*T + 64.6$ for typical tetraamide complexes of Dy^{3+} and Eu^{3+}, respectively. These temperature responses are ~690 and ~40-fold greater than that of PRF thermometry.[4] Its MRI readout signal is from bulk water present at extremely high concentration of *ca.* 55M, thereby offering the potential of thermometry measurements with high spatial resolution. The feasibility of PARACEST thermometry had been successfully demonstrated for a phantom, *i.e.,* 1 cm OD vial containing 1 mL of 10 mM EuDOTA-4AmC in water at pH 7; that sit on a 2 cm RF surface coil and in a 4.7T animal imaging magnet.[9]

In another separate experiment on the same phantom, the environmental temperature was kept constant (18°C), while the saturation power (B_1) was varied from 505 to 1515 Hz. The corresponding temperature maps (**Figure 1. Left**) clearly show the temperature increases as the higher power been applied. A plot of the average temperatures *versus* the squared B_1 values (B_1^2) shows a typical linear relationship (**Figure 1. Right**). Very interestingly, the inhomogeneous temperature increases may be detected even for such a small area with diameter of 1 cm.

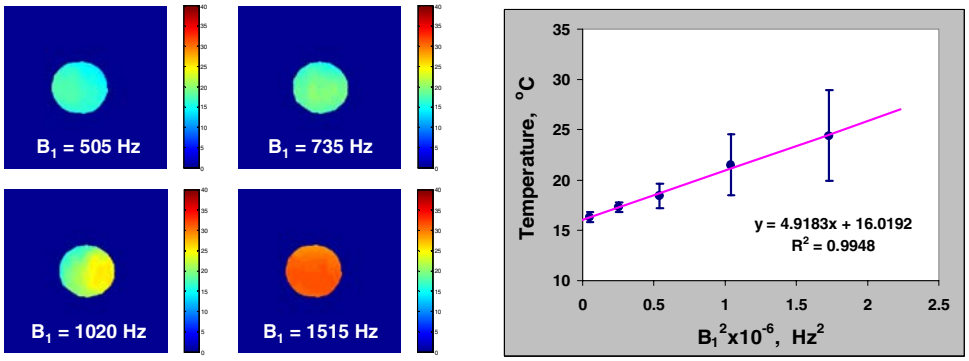

Figure 1. Left: Temperature maps of a phantom containing 1 ml, 10 mM EuDOTA-4AmC in water at pH 7.0. The environmental temperature was kept at 18 °C, while the saturation powers were varied from 505 to 1515 Hz; **Right:** A plot of the average temperatures *versus* the squared B_1 values.

Conclusions

PARACEST Thermometry had been successfully applied *in vitro* to report the inhomogeneous B_1 deposition for a 2 cm surface coil. Further experiments are still in progresses, such as by using different coils and/or demonstrating *in vivo*, etc. Nevertheless, we believe that such PARACEST thermometry may eventually find important application in reporting such as "hot-spots" in high field MRI diagnosis.

References

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