Implications of Experimental Parameters on RF Heating for High Field MRI

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Introduction

Inhomogeneous distribution of RF fields within biological tissues is typically associated with high field MRI (B_0 above 3T). This is primarily caused by the RF wavelength within the medium becoming comparable to the diameter of most body parts (e.g. the head). In addition, coil design, excitation scheme, and subject placement within the coil play an important role in determining the RF distribution. In this work, we investigate such factors by mapping the RF distribution by temperature changes and using finite difference time domain (FDTD) simulations. In this work, specific transmit schemes predicted by FDTD are used to achieve certain RF distributions. Such distributions are then validated by fluoroptic measurement of the temperature changes at the same sites [1]. These measurements also could help avoid formation of localized concentration of RF, the so-called hot spots.

Materials and Methods

A human head phantom was fabricated from approximately 5 kg (the typical mass of a human head) of ground turkey breast. The RF coil was built using transverse electromagnetic (TEM) design. It was comprised of 16-struts in transmit/receive configuration and was used in either two or four port configuration. The coil had a length of 21 cm and a diameter of 34.5 cm. It was built with the ability to excite from one single port, two port or 4 ports. It was tuned and operated at 340 MHz. To ensure the power delivery to the sample, reflected power was monitored. RF heating was measured by monitoring the temperatures using a four channels Luxtron fluoroptic thermometry system. The sample was placed in precise locations that were used for FDTD calculation. The sites of temperature measurements were also determined to coincide with the predicted high temperatures of the computational results. They represented both peripheral and deep tissues. For both measurements and computations, temperature increases due to pulse sequences with 4W/kg RF content were used for ten minutes.

Results and Discussion

The highest temperature in the deep tissues was measured for the TEM coil to be less than 1˚C using pulse sequences with adjusted parameters to deliver 4 W/kg of RF power. Computations were used to calculate the SAR values for the same amount of RF irradiation. Fast spin echo and large flip angle gradient echo sequences were used to achieve the same RF power deposition with the same temperature increases. The average temperature increase over the entire sample for all the pulse sequences was 0.4˚C for this RF coil. There was a clear difference in the heating pattern for samples as a function of sample location, transmit scheme, and coil tuning. The computational results verified these patterns. Different sample position, single excitation, quadrature excitation and 4-port excitation were used. In all measurements, it was observed that using RF coil design, the sample position and the number of excitation ports affect the amount of heat produced within biological tissues by RF pulses of the high field MRI scanners.

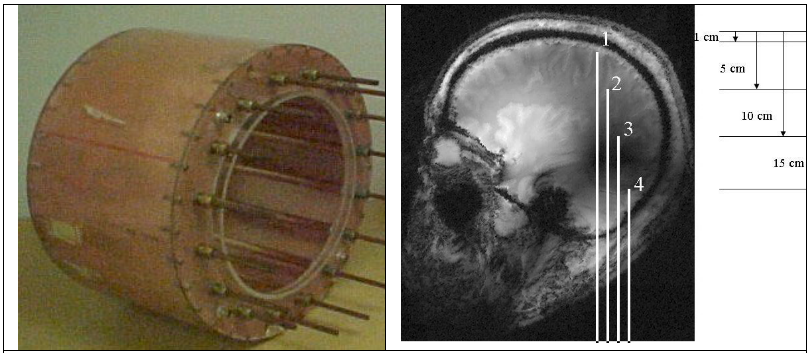

Fig.1. (Left) A TEM coil constructed with 16 struts for operation at 340 MHz. (Right) A human cadaver images is used to demonstrate both the configuration corresponding to the particular RF distribution achieved for such measurements.

Conclusion

RF thermal heating is the gravest consequence of high field MRI and it must be thoroughly investigated for high field MRI scanners. The fact that RF heat deposition increases with increasing conductivity makes this especially important for in vivo applications. As we expected, we observed inhomogeneous heating of the head phantom. The change in temperatures recorded for a modified 340 MHz TEM coil as a function of excitation scheme, sample location, and coil design is significant. This is because high filed is capable of small area heating that upon modification of RF distribution will be suppressed or broadened. In this work, we demonstrated that in addition to overall heating, the RF distribution monitored by a high precision optical technique could also be improved. In this investigation, pulse sequences were the same to ensure the effect is solely due to the positioning, excitation scheme, and coil design.

References

[1] Shellock FG, et al, Radiology, 163: 259-262, 1987.