Use of PROPELLOR for MR Thermometry

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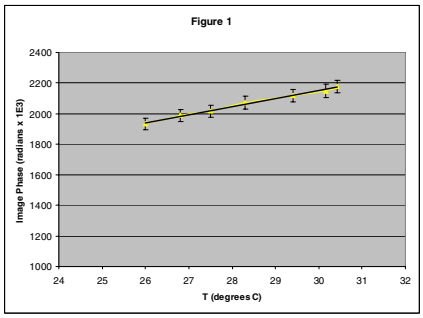
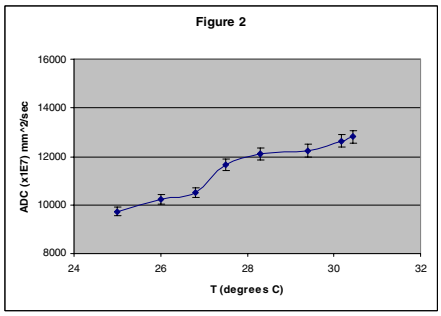
Introduction

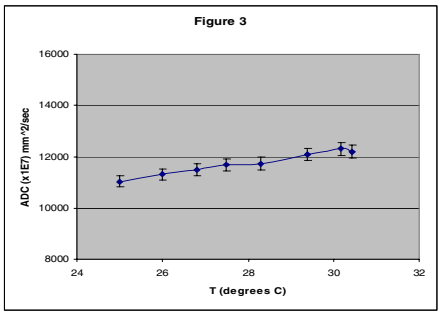
Hyperthermia has been shown to be of value as an adjunctive therapy to radiation therapy in such cases as recurrent cancer in the chest wall [1]. One of the key factors in successful hyperthermia treatment is the measurement and control of the temperature in the tumor and also in surrounding normal tissue. While invasive thermometry gives good accuracy and precision for this purpose, complete temperature mapping of a region using imaging methods is expected to afford improvements in the control of the temperature therapy distribution. Previous work has shown the value of using the temperature sensitivity of the tissue water proton resonant frequency shift (PRFS) or the apparent diffusion coefficient (ADC) to measure temperature change [2]. While the PRFS method has good temporal and spatial resolution, it suffers from sensitivity to motion and drift. The ADC method is less sensitive to motion and drift but suffers from low resolution and image distortion due to the use of diffusion-weighted (DW) single shot echo-planar imaging (EPI) methods. The development of the multi-shot PROPELLOR imaging method [3] may convey advantages in motion insensitivity and resolution for diffusion temperature change measurement. In this study we evaluate the extent to which DW PROPELLOR imaging can improve the ADC temperature change measurement method.

Methods

Tests were performed using a phantom that consists of a cylinder (12cm dia x 30cm) filled with a polyacrylamide gel that mimics the conductivity of normal tissue. This is surrounded by a second cylinder (25cm dia x30cm) that has 4 radiofrequency heating antennae spaced uniformly around the outside of the cylinder. The intervening space is filled with a distilled water bolus to provide a match. The gel section of the phantom has a central catheter along the axis which has a Luxtron fluoroptic probe placed in it in the imaged slice to provide an independent measure of the phantom temperature. The phantom was imaged at 1.5T (GE Signa Echo-speed, 23mT/m gradients) using a spoiled gradient echo sequence (TR/TE/flip=34ms/20ms/30, 128x128 matrix, 122 Hz/pixel, 9Nex) and two DW sequences: EPI (TR/TE/flip=10s/60ms/90, 64x64 matrix, 1953 Hz/pixel, 1Nex) and PROPELLOR (TR/TE/flip=800ms/86ms/90, 128x128 matrix, 651 Hz/pixel, ETL=16, 1.5Nex). The images covered a 28cm FOV with a 5mm slice thickness. DW (b=750 sec/mm^2) was applied in three orthogonal directions plus a non-DW acquisition. The scan times were all about 40 sec. Average ADC values were calculated by conventional means. Image phase was obtained directly from the reconstruction. These sequences were repeated alternately while the phantom was heated from 25 C to 30 C obtaining measurements approximately every 0.5 C. The image phase or the calculated ADC was obtained for a 1cm square ROI adjacent to the temperature probe.







Results and Discussion

Figure 1 shows a graph of the image phase as a function of the Luxtron probe temperature, indicating that the image phase increases monotonically as the temperature increases as shown by the trend line fit.. Figure 2 shows similar data for the EPI ADC measurement. The data increase monotonically with temperature but there is more variability than would be expected due to statistical fluctuations. The PROPELLOR data is shown in Figure 3, exhibiting better fidelity to the trend indicated by the phase data. In addition, the PROPELLOR sequence was able to achieve good image quality with a 128x128 matrix while the single shot EPI sequence was only able to achieve acceptable image quality for a 64x64 matrix due to susceptibility related distortion of the image. The ability of the PROPELLOR sequence to achieve higher image quality while still maintaining the diffusion sensitivity to temperature should make it a useful pulse sequence for non-invasive volume temperature change measurement.

References

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