Temperature Measurement Nearby an Iceball using the Proton Resonance Frequency method: Recalculation of Susceptibility Artifacts.

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Introduction. Minimally invasive treatments such as Laser-Induced Thermotherapy (LITT), Radiofrequency Ablation (RFA), High Intensity Focused Ultrasound (HIFU) and microwave ablation are commonly used in the clinical setting for the treatment of focal cancers throughout the body. Magnetic Resonance Imaging (MRI) based temperature monitoring is often performed in order to provide real-time feedback to the operating physician, typically using the Proton-Resonance-Frequency (PRF). Another commonly used minimally invasive local tumor therapy is cryo-ablation, which creates an ice ball to induce cell death. As for high temperature thermal therapies, it is often necessary to monitor temperature changes in real-time during a cryo-ablation procedure, particularly in at-risk structures adjacent to the target tissue/organ. Currently, temperature monitoring is performed using invasive temperature probes which must be placed by the operator, a time consuming and potentially dangerous procedure.

Considerable research was made for non-invasively measuring the sub-zero temperatures within the ice-ball itself using MR [1], however, there has been little or no investigation into using MR to measure the near-zero temperatures which are induced around the ice-ball. As long as the tissue still contains liquid water, the PRF method should be applicable. However, the ice ball itself disturbs the local magnetic field because of susceptibility contrast with defrosted tissue, which strongly influences the PRF method.

Cost function was defined as the standard deviation of the corrected temperature series (see equation below derived from ref. [2]), near the ice ball surface in the central slice. The assumption was the border of the ice ball no MR-signal is obtainable and these temperature errors were fully corrected using our method (Figure 3). Within the ice ball no MR-signal is obtainable and these temperature values were set to zero.

Results. The susceptibility difference between frozen and melted tissue was found 0.155 ppm for a best-corrected temperature uncertainty of 0.34°C (Figure 2). Figure 3 shows a corrected and non-corrected temperature image. Computing time was less than 1s in Matlab. Visible susceptibility artifacts induced temperature errors of ±6°C around the ice ball. These errors were fully corrected using our method (Figure 3). Within the ice ball no MR-signal is obtainable and these temperature values were set to zero.

Conclusion. This study demonstrates a method for correcting the peri-ice ball susceptibility artifacts induced by freezing tissue. Using an in-line post processing system, this method could be applied during clinical MR-guided cryotherapy, and allow for the non-invasive monitoring of near zero temperatures in at risk tissues adjacent to the target lesion.