

Purpose

Continuous thermometry during a hyperthermic procedure may help to correct for local differences in heat conduction and energy absorption, and thus allow optimization of the thermal therapy. In addition, MRI thermometry may help the evaluation of SAR levels.

Methods

Noninvasive, three-dimensional mapping of temperature changes is feasible with MR, and may be based on the temperature dependence of the relaxation times T_1 and T_2 , the diffusion coefficient (D), or proton resonance frequency (PRF) of tissue water. The use of temperature-sensitive contrast agents and proton spectroscopic imaging can provide absolute temperature measurements.

Results

The excellent linearity and near-independence with respect to tissue type, together with good temperature sensitivity, make PRF based temperature MRI the preferred choice for many applications. The PRF methods employ RF-spoiled gradient echo imaging methods. A precision of 1 °C, for a temporal resolution of 1 s and a spatial resolution of 2 mm, is feasible for a single slice for immobile tissues. Corrections should be made for temperature-induced susceptibility effects and magnetic field instabilities. Fat suppression is necessary for many tissues with a significant fat content when PRF methods are employed. If thermometry is desired in regions with predominant fat content, T_1 and T_2 , based methods are recommended.

Since most MR thermometry methods provide relative information, tissue displacements are among the serious pitfalls. Excellent registration is important to correct for displacements between scans. Variable reference (atlas based) methods, and the use of internal (non-heated) regions as references, have been shown to greatly improve the precision and accuracy of MR thermometry. Intrascan displacements must be monitored and corrected for. Since intrascan motion artifacts may lead to artifacts, multi-slice 2D may be preferred above 3D scans. If MR thermometry is needed for therapy adjustments, attention should be paid to real-time image processing methods.

Conclusion

When combined with minimally invasive heating methods, continuous MR temperature mapping can provide feedback coupling in order to ensure a desired temperature trajectory. It is expected that temperature MRI will provide clinical endpoints for each individual thermoablation therapy.