In Vivo Online MR Thermometry for Detection of Heat Sink Effects during Thermal Ablation of Porcine Liver: PRF-based Temperature Measurements with Pathologic Correlation

Bernd Frericks[1], Eva Rothgang[2,3], Wesley Gilson[3], Li Pan[3], Aaron Flammang[3], Jörg Roland[4], Steffi Valdeig[5], Dara Kraitchman[5], Frank Wacker[5]

[1] Department of Radiology and Nuclear medicine, Universitätsmedizin Berlin–Charité Campus Benjamin Franklin, Berlin, Germany
[2] Pattern Recognition Lab, University of Erlangen-Nuremberg, Erlangen, Germany
[3] Center for Applied Medical Imaging, Siemens Corporate Research, Baltimore (MD), USA
[4] Siemens Healthcare, Erlangen, Germany
5 Russell H. Morgan Department of Radiology and Radiological Science, Division of Vascular and Interventional Radiology, Johns Hopkins University, Baltimore (MD), USA

PURPOSE

To evaluate magnetic resonance (MR) proton resonance frequency shift (PRF) thermometry for detection of perfusion mediated tissue cooling (heat sink effects) of intrahepatic vesssels during thermal ablation in real time.

METHOD AND MATERIALS

MR image-guided insertion of radiofrequency (RF) ablation probes was performed to achieve ablation zones with varying distances from MR-visible hepatic veins and portal fields. During standardized bipolar ablation (8 ablations, 5 pigs; active tip length 30mm, power 30W, applied energy 22kJ) online PRF temperature measurements (1.5T Siemens Espree, TE 20ms, TR 51ms, FA 25°, SL 5 mm, in plane resolution 2.3 mm) were obtained perpendicular to the RF probes. The real-time PRF temperature information was displayed on a dedicated user interface at the magnet table side. Excised livers were cut into 2 mm slices and stained for Nicotinamide Adenine Dinucleotide Diaphorase (NADD). Shape and diameter of coagulation necroses on NADD were compared to the respective temperature distribution maps as well as thermal dose maps during ablation.

RESULTS

Adequate positioning of the probes at distances ranging from 2 to 20 mm to hepatic veins and portal fields was achieved in all animals. The temperature distribution maps showed a permanent compressive yield on the isotherms in the direction of the flow in the intrahepatic vessels. This effect was observed in all 8 ablations at portal fields up to a distance of 20mm corresponding to a flattening of the coagulation zone on gross pathology. The cooling effect was significantly less pronounced adjacent to hepatic veins where isotherm compression was only observed in 3 ablation zones with veins less than 10 mm away.

CONCLUSION

Online PRF measurements provided a guide to determine heat sink effects during ablation.

CLINICAL RELEVANCE/APPLICATION

PRF Thermometry during liver tumor ablation can help to detect perfusion-mediated tissue cooling, facilitates immediate MR-guided repositioning of the RF probes and therefore might enhance accuracy.