MRI assisted thermotherapy enhanced by optical invasive measurement

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Purpose/Introduction:

Various coagulation methods such as the interstitial laser thermo-therapy (ILTT) or radiofrequency coagulation are under clinical investigation. MRI techniques were used to characterize coagulation (i.e. T2 weighted images) or temperature changes for monitoring and for further improvement of these methods. To overcome inconsistencies like reduced image quality due to susceptibility induced distortions additional information about tissue response would be helpful. The purpose of the present study was to investigate a device for the detection of the actual state of the treated tissue by measuring the change of the optical diffuse reflectance of coagulated tissue during MRI.

Material and Methods:

ILTT of the tissue (turkey-muscle) was induced by a temperature controlled 830 nm diode laser (Indigo 830e/20, Indigo, Palo Alto, USA) applying initially a maximum power of 10 W to receive a maximum temperature of 90°C. Reaching 90°C at the tip of the laser fiber, the power was regulated automatically to maintain this temperature. The temperature feedback is facilitated by an temperature probe at the laser fiber tip. Laser power was switched off when a strong signal change was detected by the coagulation detection unit.

This coagulation detector unit is based on the measurement of a diffuse reflected test light. The test light (630 nm, 5 mW) is transported to the point of interest by an optical bare fiber. The intensity of a certain amount of the test light that is back scattered into the fiber could be registered at the distal end. The back scattering is dependent on the optical properties of the tissue such as whitening due to coagulation, meaning increase of the scattering coefficient. Coagulation induced changes of optical properties will therefore result in a change of signal. Furthermore an additional temperature probe (model FT 707, IRE-Polus Co., Russia) was positioned in a distance of about 6 mm relative to a laser fiber.

Five experiments were performed under control by means of a 1.5 Tesla whole body MR-system (Magnetom Vision, Siemens Medical Solutions, Erlangen, Germany). Temperature sensitive parameter maps were generated by mapping the temperature dependent phase change acquired by a 2D-FLASH sequence (TE = 30 ms; TR = 150 ms; flip angle=35°) [1]. The phase change was displayed online on the MRI–control monitor by a software developed in our institute. An additional temperature monitored gel phantom was used as a reference. Post-ILTT T2 and proton density weighted images (double echo tSE; TE = 14/85ms; TR =2300ms) were acquired to characterize the position of the detector probe relative to the coagulated tissue. Outside the MRI a visual inspection of the detector position relative to the coagulated tissue was also performed.

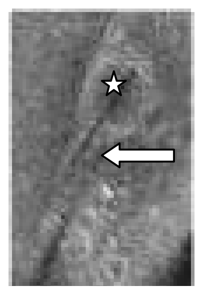

Fig. 1: Position of the detector probe (arrow) relative to the bright rim of the coagulation zone in the T2w MR-image and the laser fiber (*)

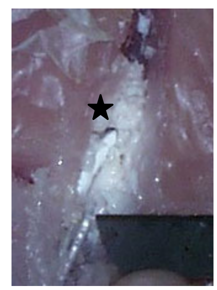

Fig. 2: Position of the coagulation detector probe (knife tip) relative to the white area of coagulated tissue and the laser fiber (*)

Results:

The signal of the coagulation detector unit followed a sigmoidal course, detecting the onset of coagulation at the tip of the probe. A 36 ± 9% signal increase was recorded when the coagulation zone arrived the probe. The absolute detector signal varies according to the composition of the tissue. The mean value before ILTT was 2,8±1,3V. Beside the signal void no additional MRI artifacts were detected. In the T2- or PD-weighted MRI image the position of the detector probe clearly correlated with the bright rim of the coagulated tissue (Fig. 1). This was within the spatial resolution of the MR-image (1 mm in plane and 3 mm slice thickness). The correlation with MRI was also verified visually by dissecting the muscle phantom at the position of the detector probe (Fig. 2). The visual findings correlated with results found in experiments outside the MRI. The maximum temperature at the detector tip was calculated to be 59 ± 6 °C at a mean distance of detector and Laser probe of 4 ± 1 mm.

Discussion/Conclusion:

The coagulation detector unit supplied online information on the local changes of optical tissue properties accompanying tissue changes during ILTT. The device was tested successfully in tissue phantoms during MRI. No additional artifacts were observed. The detector can be implanted minimal invasively and enhances online MRI-characterization by adding local optical tissue information. In the development of MRI-monitoring and feed back loops for thermotherapies it may be used to test online and locally the prediction values of the new MRI-methods ex vivo and also in vivo. In cases of impaired image quality the new detector may also serve as a switch-off criteria for thermotherapy when implanted with the laser probe. Further experiments for example will have to investigate what time point or infliction point of the sigmoid detector signal – time curve is most useful as a switch-off criteria.

References: 1) M. Peller, A. Muacevic, R. Sroka, L. Ruprecht, M. Reiser. [2003] ISMRM, p. 892