Is the thermal dose a reliable and precise indicator of tissue ablation? A pig liver radiofrequency thermo-ablation under quantitative MR-temperature mapping

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Purpose/Introduction

Radiofrequency (RF) ablation is a well known technique for the treatment of liver cancer. MRI is the only imaging modality allowing a non-invasive and quantitative measurement of local temperature distribution and thus the calculation of cumulative thermal dose (TD). The purpose of the present study is to evaluate the accuracy of TD as an indicator of induced necrosis. TD maps are calculated on-line from real-time temperature imaging (based on the Proton Resonant Frequency, PRF, method [1]) simultaneously with RF ablation in pig liver with a clinical device.

Subjects and Methods

The animals (n=4) were maintained under general anaesthesia and positioned inside a 1.5T Philips MR system. An internally cooled MR compatible RF needle (Radionics cool-tip, Tyco healthcare, USA) was inserted in the liver (14 ablations in total). Electrical interferences of the generator (200W max output power) were suppressed by inserting in the transmission line 2 rejection filters (total attenuation > 100dB) tuned to the proton resonance frequency (64 MHz). A Standard RF ablation protocol (12 minutes) was performed simultaneously to continuous MRI acquisition of RF spoiled, segmented-EPI gradient echo images (240mmFOV, 128x128Matrix, 3slices, 6mm thickness, 9 echos/TR, TE/TR=16/250, FA=30°-binomial selective water excitation, respiratory gating, 4s/3 slices). Temperature images were calculated on-line from dynamic phase images and were used to compute the cumulative thermal dose (using equation in ref [2]).

After completion of the ablations, animals were sacrificed and the liver was removed for histological examination. Livers were fixed in 10 % formaldehyde and sectioned. The central burn holes associated with different electrode positions were used as landmarks for image analysis. The largest diameter perpendicular to the electrode axis was measured and correlated to the dimensions obtained from the corresponding thermal dose maps. After paraffin embedding, 5 micrometer thick sections were stained with Hematoxylin-Eosin-Saffron (HES) for evaluation of tissue damage, and with Gordon-Sweets reticulin stain for evaluation of the preservation of the extra cellular matrix.

Results

High quality temperature maps were obtained, with a 1.6°C standard deviation of temperature calculated from phase stability measurements in non heated regions, with identical values before and during RF application. No residual artifact due to electromagnetic interferences was observed, except a 10% reduction in SNR during RF deposition. The artifact induced by the needle was15±2 mm (image A). Typical maximal temperature increase above body temperature was in the range of 50°C. An excellent correlation (r=0.98) between TD and histological measurement was found (see figure 1C). Microscopic analysis of tissue (HES coloration and Gordon-Sweets reticulin stain) confirmed complete necrosis in the heated region.

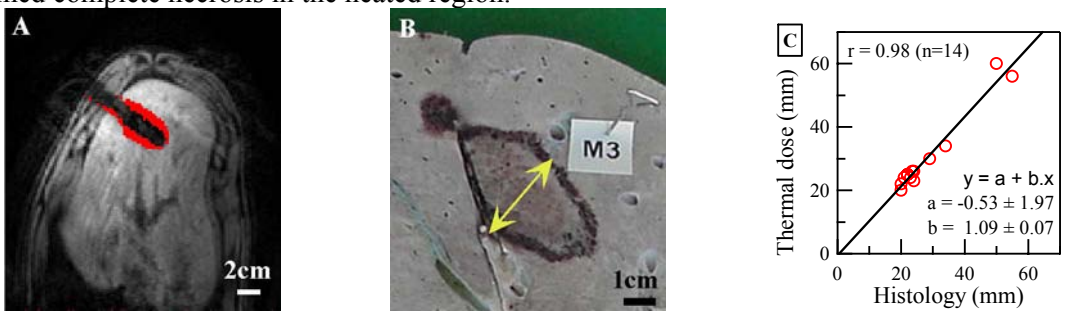

Figure 1 : Image (A) shows typical resulting TD map at the end of RF heating (red pixels indicate pixels reaching lethal thermal dose). Image (B) is a photograph of the liver showing the RF ablation zone. The yellow arrow indicates measurement taken for comparison with TD. Graph (C) displays the correlation between measurements performed on images such as those shown in (A) and (B).

Discussion/Conclusion

This study demonstrates that temperature maps of excellent precision can be obtained on pig liver *in vivo* on a clinical scanner simultaneously with RF ablation, using appropriate filtering. Apparent lesion dimensions measured on TD maps are in good agreement with histology. This study indicates that TD is an excellent indicator for predicting the actual lesion dimension while performing the ablation.

References

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