

# Volumetric Ablation of tissue using Magnetic Resonance Imaging guided High Intensity Focused Ultrasound (MRgFUS) with feedback control and multi-slice thermal monitoring: Initial experience in a pig model

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## Introduction:

MRgFUS is increasingly finding clinical applications for non-invasive ablation of tumor tissue within the body. A recently proposed method provides an integrated approach that exploits the real-time capabilities of modern MRI scanners. This system provides the ability to heat a volume of the tissue by dynamically moving the focal point of the ultrasound beam by monitoring the temperature elevation in real-time across multiple planes, and the ability to discontinue treatment once the target thermal dose is reached. The purpose of the current study is to describe the preliminary results from volumetric ablations with real-time feedback control in a pig model.

## Methods:

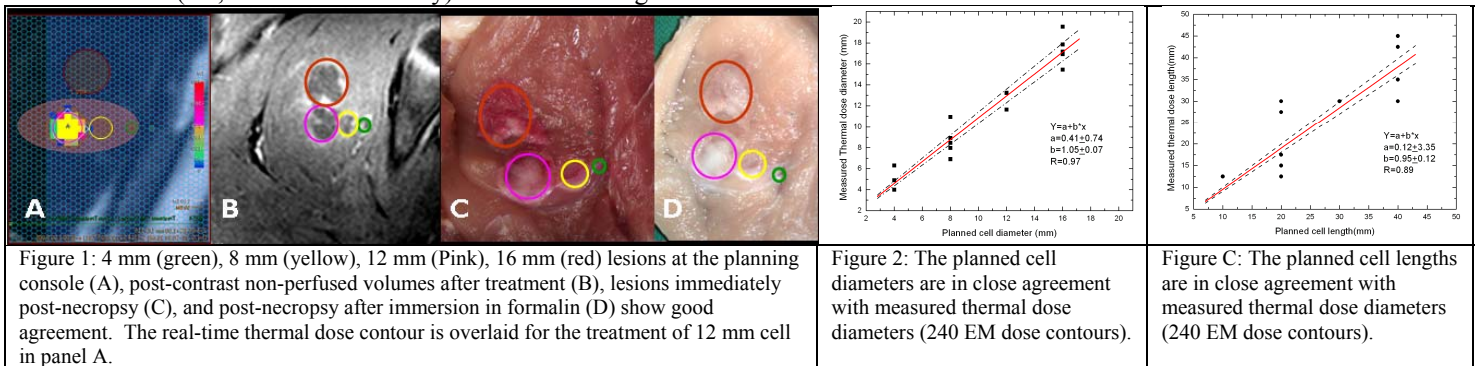
**Animal Care:** The study was approved by the Institutional Animal Care and Use Committee (IACUC). Thermal lesions were created in the thigh muscle of five pigs (50-65 kg) using the volumetric MRgFUS procedure. The animals were under sedation throughout the procedure, and were sacrificed immediately after the procedure under Institutional guidelines.

**MRgFUS procedure:** All experiments were done on a Philips 1.5T MR scanner (Achieva) with a modified table-top that had a 256 channel spherical shell HIFU transducer with five degrees of freedom, and an integrated surface coil suitable for imaging. The ultrasound (US) frequency ranged from 1.2 to 1.4 MHz. 22 volumetric sonications that were designed to cause lesions with cell diameters of 4 mm, 8 mm, 12 mm, and 16 mm were applied to the legs (Figure 1A). In 15/22 cells (i.e., feedback treatment cells), the treatment was discontinued after the real-time thermal dose calculation indicated that the target tissue attained the predicted thermal dose (240 EM at 43°C), and 7/22 cells were treated with a fixed duration (i.e., non feedback treatment cells).

The temperature elevation was monitored in real-time using a multi-shot echo planar imaging technique with the following acquisition parameters: TE=20ms, TR=37ms, resolution=2.5x2.5x7mm<sup>3</sup>, EPI-factor=11 and 121-binomial water selective excitation pulse. A total of six slices were prescribed to monitor the temperature elevation; three coronal slices bisected the focal ellipsoid coronally, and one sagittal slice was positioned to visualize the long axis of the ellipsoid. Two additional slices were placed at the near field and far field to monitor any unintended temperature elevation. The total acquisition time for all six slices was 2.9 s. A post-contrast MR image was acquired to determine the non-perfused region immediately after treatment.

## Results:

19/22 cells were successfully treated. In one case, the treatment was automatically discontinued by the safety algorithm once the near-field temperature exceeded the safety limit, and in 2/22 cases, the treatment failed due to equipment malfunction. Gross examination of the lesions revealed ellipsoidal thermal lesions with sharp boundaries between the treated and untreated areas (Figure 1), and did not reveal any damage in the near field. Planned cell diameters, and cell lengths agreed closely with measured thermal dose diameters (Figures 2, 3). Comparison of acoustic energy deposited against the lesion volumes suggest that energy required to induce a given lesion volume (i.e., treatment efficiency) decreases for larger cell sizes.



## Conclusions:

The results from this preliminary study suggest that:

- (i) it is feasible to create cell sizes of varying sizes by dynamic displacement of the focal point of the US beam;
- (ii) the measured diameters and lengths of the cells from the thermal dose contours agree closely with planned cell diameters and lengths, and
- (iii) real-time monitoring of thermal dose evolution in multiple planes, and real-time feedback control can provide crucial safety controls that can trigger treatment aborts when user-prescribed limits are exceeded.

## References:

1. K. Hynnen et al. Radiographics, 16, 185-95, 1996;
2. Kohler et al., Med. Phys. 36(8): 3521-3535, 2009.