

# Truly simultaneous clinical US/MRI: dual mode visualization of bubble creation during RFA inducing susceptibility variations corrupting PRFS thermometry

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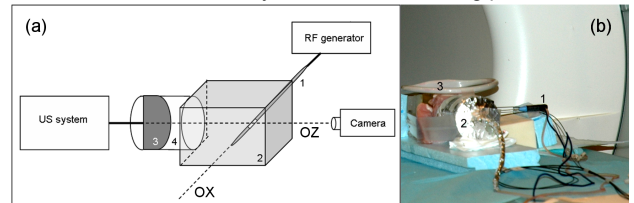
## Introduction

Recent work reported spatially related errors in temperature maps and TD during power application, while using 2D GRE-EPI PRFS imaging with orthogonal interleaved slices (1). We demonstrate that RFA induced cavitation's effects are the primary source of errors in PRFS imaging using truly simultaneous ultrasonography and MRI.

## Materials and Methods

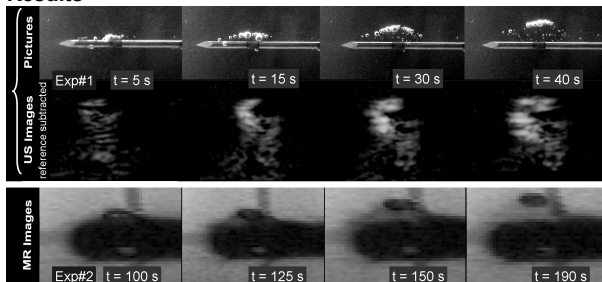
MRgRFA imaging was performed on a 1.5T MR system (Espree, Siemens AG, Germany) using 2D GRE-EPI PRFS imaging with orthogonal interleaved slices as previously described(1). Experiments were performed *in vitro* on an optically transparent gel (15% alimentary gelatin (saturated but fluid at 95°C) doped with 9g/litre NaCl to ensure an electric conductivity) mimicking tissue and on fresh samples of Turkey white muscle and porcine liver. A standard digital still camera was used for optical monitoring of RF heating procedures performed in gelatin gel. US imaging was performed using a MR Compatible prototype US scanner (Antares, Siemens Medical Solutions, Mountain View, CA, USA) equipped with Contrast Pulse Sequence imaging (CPS). The CPS technique processes the reflections of a series of US pulses to optimize the contrast to noise ratio (CNR) and allow the construction of a contrast-only image. The non-magnetic CH4-1 transducer (256 element phased array) was fixed in a plastic-made cylindrical tube that was filled with degassed water and sealed by a US-transparent membrane. Ultrasound imaging slice was always orthogonal to the RF electrode and carefully aligned with the anode/cathode gap of the RF electrode, see Fig1.a. Single focus mode was used with focal length adjusted to match the RF electrode position. The frame rate was 12.5 images per second. For grey scale imaging, the US gain/frequency/ dynamic window/ Balance/ speed-resolution-ratio/acoustic intensity parameters were -4dB/ 1.33MHz/ 70dB/ 2D / 2/ 14 mW/cm<sup>2</sup> and for CPS imaging they were set to -20db /3.08MHz /50dB / CA(Contrast Agent) /2/ 42 mW/cm<sup>2</sup>. When the US imaging device was operated simultaneously to MRI acquisition, the cylindrical tube accommodating the US transducer and the

transmission line of the US probe (7m long) were entirely shielded (see Fig1.b) except for a rectangular 2x8cm aperture in front of the US transducer. The transmission line was passed through the Faraday cage via a waveguide tube, with common ground contact between the Faraday cage and the electromagnetic shielding. In dual modality imaging experiments, US and MRI acquisitions were started simultaneously to monitor RF heating procedures.



**Fig1.** a) Diagram for the experimental setup in ultrasound and digital camera monitored RF heating (Exp#1). Shown are 1: Bipolar RF Electrode, 2: Saline gel (15% alimentary gelatin, 0.9% NaCl), 3: MR compatible ultrasonic transducer and 4: Degassed water within the cylindrical tank. b) Experimental setup for simultaneous ultrasonography and MRI monitoring. Visible are: 1. MR compatible RF electrode, 2. EM-shielded transducer holder and 3. Receive only MR loop coil.

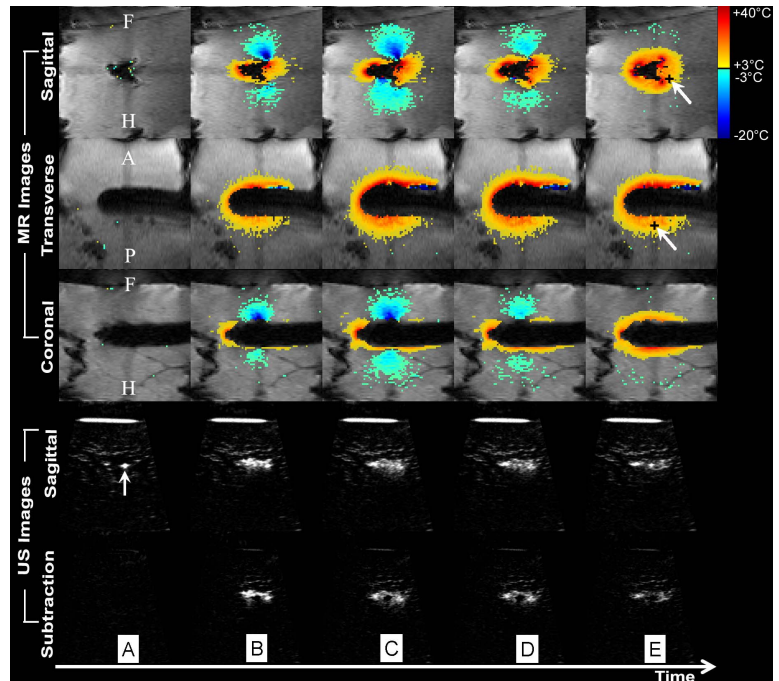
## Results



**Fig.2.** **First row:** digital images of the RF electrode over time in saline gel, from RF power onset point ( $t=0$ ) to the cut-off. A cloud of gas bubbles is created over time, centered with the anode/cathode gap. **Second row:** reference subtracted US images from the same experiment acquired in the plane orthogonal to the RF electrode and corresponding to the same time points as digital camera shots. See the white cavitation cloud. Note that identical magnification factor was used in US and digital camera images. **Third row:** MR images obtained during RF heating in a separated experiment in identical saline gel. See the dynamic hypointense artifact above the main static artifact, illustrating a gas bubble detaching from the electrode.

## Discussion and Conclusion

To our best knowledge, truly simultaneous US and MR imaging using a clinical-standard US scanner whilst producing interferences-free US and MR images, has not been reported earlier. Dual modality imaging was used here to demonstrate the formation of cavitation's bubbles during RFA. Based on the experimental facts described here, disruptive changes in the local bulk susceptibility of tissue are considered as the principal whilst not the only significant physical cause of the reported large errors in PRFS MR-thermometry *ex vivo*. In static tissue, these magnetic susceptibility-mediated cavitation's effects are far outweighing all other competing sources of error. On-line correction is considered mandatory in order to provide clinical benefit from MR monitoring of the RFA. Indeed, temperature evolution has to be accurately measured throughout the RFA treatment to permit correct assessment of the delivered thermal dose, and thus a clinically pertinent cut-off point for energy application.



**Fig3.** Multimodal monitoring of high power (30W) RF application in *ex vivo* tissue. The RF electrode and two optical probes were placed orthogonal to  $B_0$ . Synchronized MR/US images covering the same FOV (80mm square) are shown from left to right at  $t = 10s, 100s, 145s$  (peak heating),  $150s$  and  $200s$  (columns 1-5 respectively). 1<sup>st</sup> to 3<sup>rd</sup> rows display time series of sag/cor/axial MR magnitude images with overlaid PRFS temperature maps. Apparent PRFS-derived temperature variation is indicated with a color map ranging from blue ( $-20^\circ\text{C}$ ) to red ( $40^\circ\text{C}$  and above). 4<sup>th</sup>/5<sup>th</sup> rows show times series of second harmonic US images (CPS mode) in sagittal plane, direct images and temporally subtracted images. The arrow indicates the electrode. Gas bubbles created by RF heating are clearly seen in the US images and correspond to concurrent dynamic geometrical distortions of the MRT maps. **References:** (1) Viallon M. proc ISMRM 2009. (2) Boss MRM 2009