Non-Contrast Assessment Microvascular Blood Flow Fraction to Evaluate Treatment Efficiency of MR guided High-Intensity Focused Ultrasound (MR-HIFU) Surgery of Uterine Fibroids

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Introduction: MR-HIFU surgery of uterine fibroids can provide symptomatic relief (Gorny et al. JVIR, 2011). MR-HIFU surgical approach permits physician to visualize the target tissue and plan *before* treatment, monitor treatment *during* ablation and assess efficacy *after* treatment via MRI. In current clinical practice, non-enhancing regions after Gadolinium based contrast agent (GBCA) administration are used as surrogate markers of successful treatment. Due to concerns that the stability of GBCAs may be compromised by heating, such contrast-enhanced studies are performed at the end of MR-HIFU surgery, and GBCA administration is restricted in subjects at risk for developing nephrogenic systemic fibrosis (NSF). In this study, we sought to evaluate non-contrast imaging alternatives that can yield information regarding MR-HIFU treatment efficiency. In specific, we evaluate the following MR metrics for evaluating MR-HIFU treatment efficiency: (a) T_2 maps (surrogate for edema), (b) Blood-flow fraction (*f*) maps (surrogate for tissue perfusion weighted imaging (PWI) or low b-value diffusion acquisition), and (c) ADC maps estimated from Diffusion Weighted Imaging (high b-value DWI as a surrogate for restricted diffusion).

Method: In this IRB approved study, within 10 minutes after the conclusion of MR-HIFU treatment (Sonalleve, Philips Healthcare) two data-sets were acquired prior to GBCA administration. (i) A 12-echo spin-echo (SE) sequence was used to calculate T_2 maps with the following parameters: TE/ΔTE/TR: 12 ms/12 ms/2000 ms; acquired voxel size: 3 x 3 x 5mm^3; scan time: 3:12 min; (ii) A multi-b value DWI scan with following parameters: TR/TE: 2500ms/69ms, b = 0, 10, 20, 40, 60, 200, 450, 900s/mm^2; acquired voxel size: 3 x 3 x 5 mm^3; scan time: 2:38 min. Conventional T_1 weighted post-contrast images were acquired to assess non-perfused volume 5 min after GBCA injection (CE-MRI).

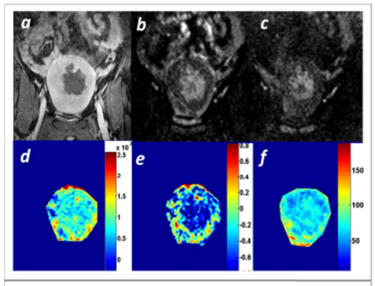

Figure1.
a. CE-MRI b. DWI (b = 60mm²/s) c. DWI (b = 900mm²/s)
d. ADC map e. f map f. T_2 map

Data Analysis: All processing was done offline using custom-written software in MATLAB™. Pixel wise T_2 maps were generated from multi-echo spin echo data set. Pixel wise blood fraction '*f*' maps were generated using the asymptotic fit technique using the intra-voxel incoherent motion (IVIM) model[1] using the three highest 'b' values and 'b = 0'value [2], and ADC values from high b-value acquisition (b = 900s/mm^2). Relative enhancement (RE) was defined as (RE %): ($SI_{untreated}$ – $SI_{treated}$)/$SI_{untreated}$ x 100. Non perfused volume (NPV) from CE-MRI was used as the reference for all comparisons. The degree of overlap between NPV and other metrics was assessed using DICE similarity measure.

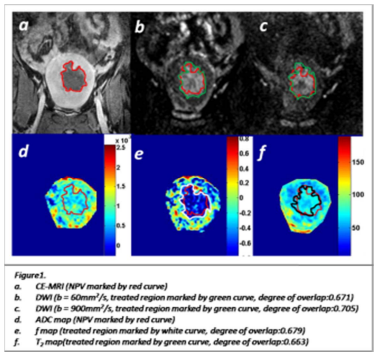

Figure1.
a. CE-MRI (NPV marked by red curve)
b. DWI (b = 60mm²/s, treated region marked by green curve, degree of overlap:0.671)
c. DWI (b = 900mm²/s, treated region marked by green curve, degree of overlap:0.705)
d. ADC map (NPV marked by red curve)
e. f map (treated region marked by white curve, degree of overlap:0.679)
f. T_2 map(treated region marked by green curve, degree of overlap:0.663)

Results: Representative qualitative (CE-MRI, PWI, DWI) and parameteric maps (T_2, f, ADC) are shown (Fig. 1). The RE of T_2, PWI, DWI, and f-maps were: 33, 40, 48, and 63.3 respectively. In treated regions, blood volume fractions (f-value) deceases from 30% to a very low value (70% pixels have f<10%), T_2 values increase from 51ms to 68ms, compared to untreated regions. DICE similarity measurements of NPV overlapping with T_2 map, DWI, and f map (Fig.2) give very similar values.

Discussion: As a metric for evaluating MR-HIFU treatment efficiency NPV is an imperfect measure. As GBCA contrast diffuses into treated regions via diffusion, NPV reduces over time even if there is no underlying change in pathology. Results from this study suggest that PWI (low 'b' value DWI) can be an effective non-contrast qualitative alternative to NPV that is uncorrupted by such effects. While ADC of treated region doesn't change too much. Furthermore, the evolution of edema over several hours/days after acute injury and the corresponding prolongation of T_2 can hamper estimating treated area via DWI[3] but this does not affect the estimation of *f*–map. Quantitatively, in treated regions *f*-map is close to zero (the negative value showed in f map caused by the low SNR, and the true value for this kind of pixels should approach 0.).

Conclusions: PWI (low 'b' value) is a non-contrast alternative to conventional NPV based estimation of MR-HIFU treatment efficiency. The blood-volume fraction map (*f*-maps) provide better delineation between treated and untreated regions than T_2 map, or conventional ADC map, and is more insensitive to other confounding factors such as T_2 changes after HIFU treatment.

Reference:

[1]Le Bihan D et al. Radiology161(2): 401-7. 1986

[2] *James Pekar et al*, *MRM 23 122-129 (1992)*

[3] Michael A. Jacobs, Am. Assoc. Phys. Med37(9): 4768-4776(2010)