MR-GUIDED HIGH INTENSITY FOCUSED ULTRASOUND FOR ABLATED KIDNEY: MR PERFUSION ASSESSMENT AND MICROSCOPIC CHARACTERIZATION

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Target Audience: Clinical and experimental investigators who use MR-guided high intensity focused ultrasound (MRg-HIFU) for treating tumors in soft tissues.

Purpose: To demonstrate renal perfusion deficits, as an early indicator, of successful thermal MRg-HIFU ablation and microscopically characterize ablated lesions.

Methods: Kidney ablation was performed on a Discovery MR 750w 3T scanner (GE Healthcare, Waukesha, WI). To minimize the effects of diaphragm motion during inspiration and expiration, rocuronium was used with a breath hold. Both left and right kidneys were ablated (24 lesions) in six pigs using frequency of 1.1 MHz and 3000 J and 4400 J spot energies. Saturation recovery gradient echo sequence was acquired after ablation to monitor regional perfusion in healthy and ablated renal tissue. Imaging was performed 2hrs after bolus (5ml/sec) injection of Gd-DTPA (2.0mmol/kg). Imaging parameters were slice thickness=3-5, slices=20, TR/TE/Flip Angle=4.5ms/2.2/20°, FOV=26cmX26cm matrix=512 (192x192), NEX=1, BW=62.5, T=5'18" and phases=15. Regional signal intensity was monitored in the ablated, viable and aortic blood (as arterial input function) for 2min to obtain perfusion data. Four hours after sonication, the animals were perfused with 4% formalin to ensure proper fixation of the kidneys. Both kidneys were macroscopically examined and excised. Stained microscopic sections (5µm) were used for characterization of vascular integrity. Paired Student *t*-test was performed to assess the significance and A *P*-value less than 0.05 was considered significant.

Results: Perfusion MRI demonstrated the ablated renal tissue as a hypoenhanced zone compared with surrounding viable tissue (Fig. 1). The perfusion deficit was visible for 5 min after contrast administration. Regional signal intensity revealed that ablated tissue has almost no perfusion (Fig. 2). Macroscopic visualization of the excised kidneys revealed the presence of multiple lesions (Fig. 3). Microscopic examination of the ablated kidneys demonstrated vascular damage and hemorrhage caused by MRg-HIFU (Fig. 4). These effects are dependent on the applied sonication energy.

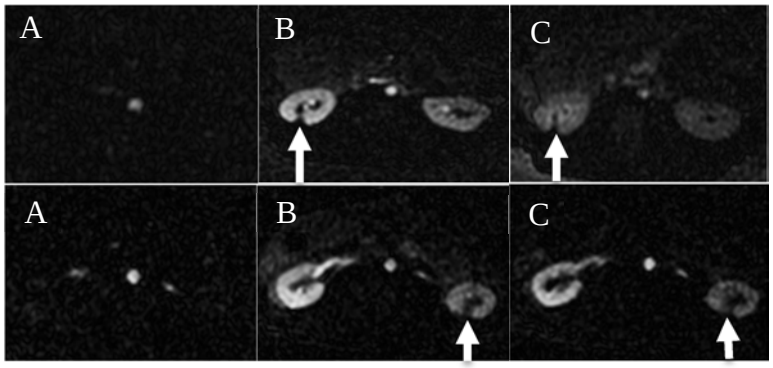

Fig. 1: Selected perfusion MR images acquired at the arrival of Gd-DTPA bolus (A) in the aorta and 20sec (B) and 120sec (C) after arrival in the kidneys of two representative animals. Arrows denote the hypoperfused lesions.

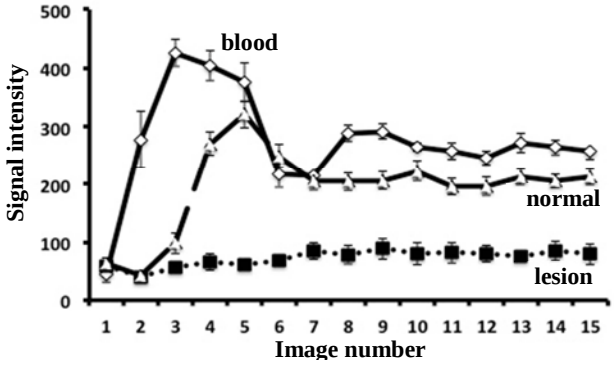

Fig. 2: MR Perfusion demonstrates severely hypoperfused ablated lesions after MR-guided HIFU compared to normal tissue. Diamond = aortic blood, triangle = viable renal tissue and square = ablated lesion.

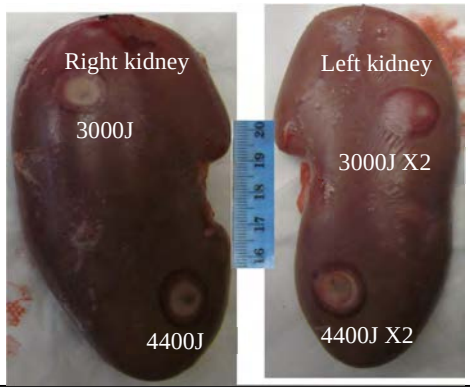

Fig. 3: Macroscopic lesions in the right and left kidney are shown after applying single and double sonication, respectively. Note that the double sonication produced visibly larger lesions compared with single.

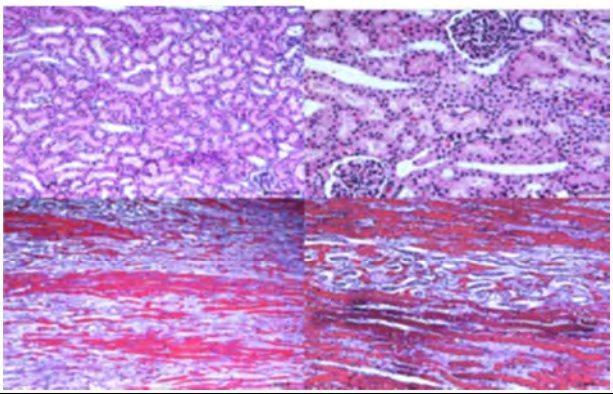

Fig. 4: Microscopic sections (H&E) of a normal kidney (top) and ablated kidney (bottom) show damaged nephrons, edema (bottom left) and hemorrhage (bottom right).

Conclusion: This is a seminal study for examining the thermal effects of MRg-HIFU on renal perfusion. It shows the potential of perfusion imaging as an early indicator of successful HIFU ablation. MRg-HIFU causes simultaneous loss of vascular integrity and cellular necrosis as shown on microscopy. The severity of the injury appears to be dependent on the energy and frequency used. Thus, the used energy and frequency must be optimized in the kidney and other soft tissues for future translation to clinic.