Comparison of Multi-contrast MRI for Characterization of Irreversible Electroporation Ablation Zones in a Pig Liver Model with Histopathologic Correlation

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Target Audience: Clinicians and physicists interested to use MRI for non-invasive monitoring of IRE procedures.

Purpose: Irreversible electroporation (IRE) is a new technique for minimally invasive local tissue ablation where the main mechanism is nonthermal[1]. Multi-contrast MRI has potential to non-invasively monitor IRE procedures[2,3]. The purpose of this study was to evaluate multi-contrast (T2w, T1w pre and post contrast agent, and diffusion weighted imaging (DWI)) MRI for characterizing the size of lethal tissue ablation zones created by irreversible electroporation (IRE) in normal pig liver and correlate with histopathology.

Methods: All procedures were approved by the local animal ethics board. In three anaesthetized pigs, 13 IRE ablation zones (lesions), including 9/2/2 with single/double/quadruple ablation, were created in the normal liver under CT and US guidance. 3 T (Trio, Siemens Healthcare, Erlangen, Germany) MRI scans were performed 50 hours after IRE: T1w MRI (2.0x2.0x2.0 mm^3) pre and 20-30 min post administration of an MR contrast agent (Eovist n=2, Magnevist n=1), post-contrast T2w MRI (1.1x1.1 mm^2, slice thickness ST=5 mm), and diffusion weighted MRI (DWI) with b-values 50,400,1000 s/mm^2 (1.8x1.8 mm^2, ST=5 mm). Pigs were sacrificed immediately after MRI (52 hours after IRE) for gross pathology sectioning with histology. MR images were analyzed in 3D software (OsiriX). Regions of interest were drawn in lesions, normal tissue and background to calculate contrast to noise (CNR) ratios. Lesion short axis diameters were measured on T1w and T2w MRI (reported as mean±std) and statistical analysis for correlation with lesion size by pathology was done using Pearson's correlation.

Results: All 13 IRE lesions were clearly visible on multi-contrast MRI (**Fig 1**). Lesions appeared hyper-intense with sharp boundaries on T2w MRI and hyper-intense but less conspicuous on DWI. Lesions were hypo-intense in pre-contrast T1w images and on post-contrast T1w MRI, lesions were hyper/hypo-intense after injecting Magnevist/Eovist (**Table 1**). Lesion size increased from 12.6 mm (single ablation) to 20.0 mm (quadruple ablation) (**Fig 2**). On MRI, lesion size as compared to pathology was within 17% for T2w MRI and within 8% on T1w MRI (pre-post subtraction) (**Table 2**). There was a significant correlation of lesion size by pathology with measurements on T1w MRI (rho=0.93, p-value<0.01) and T2w MRI (rho=0.72, p-value=0.03).

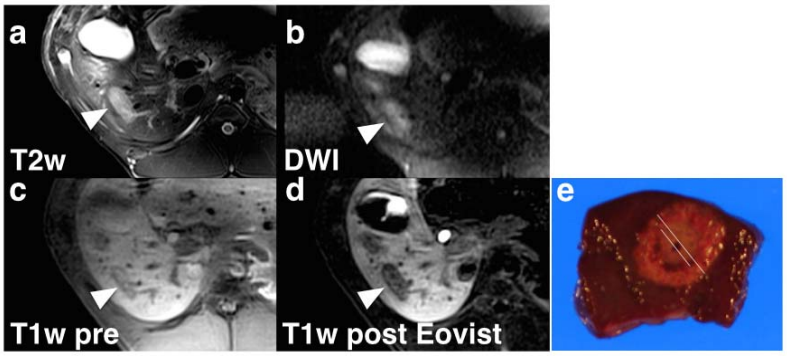

Figure 1: Example of IRE lesion (arrow) on T2w (a), DWI b-value 400 s/mm2 (b), T1w pre (c) and 20 min post administration of Eovist (d). Pathological specimen cross section through lesion shown in (e).

Discussion: IRE ablation zones are clearly visualized with multiple MRI contrasts in a normal pig liver model. T2w MRI has the highest lesion-to-normal CNR, followed by post-contrast (Eovist) T1w MRI. Lesion short axis from both T2w and T1w MRI are correlated with pathology.

Conclusion: Multi-contrast MRI has potential for non-invasive monitoring of IRE procedures and characterization of lesion size.

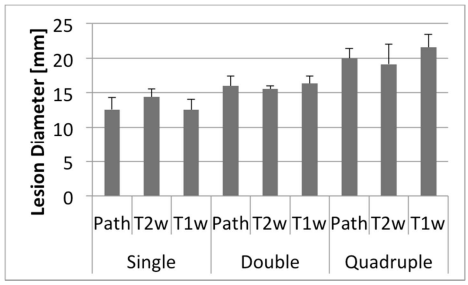

Figure 2: Lesion short-axis diameter increases with more intensive ablations. MRI size measurements from T1w and T2w images both agree with pathology.

MRI Seq	Diff b1000	Diff b400	Diff b50	T1w post Eovist	T1w post Magnevist	T1w pre	T2w
AVG CNR	7	16	36	*85*	28	*11*	162
CNR/CNR_{T2}	4%	8%	17%	*50%*	23%	*6%*	100%

Table 1. CNR measurements for multiple MRI contrasts. T1w pre and T1w post Eovist images yielded hypo-intense contrast in the lesion (reported in *italics*).

	Single			Double			Quadruple		
	Path	T2w	T1w	Path	T2w	T1w	Path	T2w	T1w
Mean ± Std [mm]	12.6 ± 1.7	14.4 ± 1.2	12.6 ± 1.5	16.0 ± 1.4	15.6 ± 0.5	16.4 ± 1.1	20.0 ± 1.4	19.2 ± 2.9	21.6 ± 1.9
Diff vs. Path [%]		17 ± 21	1 ± 12		-3 ± 6	2 ± 2		-5 ± 8	8 ± 2

Table 2. Lesion size measurements.

References: **1.** Guo Y, et al. *Cancer Res.* 2010;70(4):1555-63. **2.** Zhang Y, et al. *Radiology* 2010;256(2):424-32. **3.** Gui Y, et al. *Radiology* 2011;258(2):461-468.