MRI-guided Cryoablation - Acute Cryolesion Assessment with T1, T2 Imaging

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Introduction

MRI-guided cryoablation allows imaging of the ice ball boundary in 3 dimensions with excellent contrast between frozen and normal tissue. Previously, it has been shown that cryolesions are visible immediately after treatment as an area of low signal on contrast enchanced (CE) MR images and that the boundary of coagulative necrosis lies within the contrast enhancing rim [1]. It has also been shown that the acute cryolesion appears as low ADC [2] and and low MT contrast [3]. In some of our experiments, the lesion was visible on T2 and T1-weighted images, while in other experiments, it was not. The purpose of this work was to revisit the appearance of acute cryolesions on conventional T1 and T2 weighted images, investigate the cause of the variability on T2, and compare the lesion boundaries on T1 and T2 to those on CE images.

Methods

Seventeen adult male mixed breed dogs were anesthetized, intubated, placed in the 0.5T GE Signa SP MRI scanner and imaged with a receive-only endorectal coil. Cryoablation was performed using a MRI-compatible cryotherapy system (CryoHit, Oncura). Seventeen-gauge MR compatible cryoablation probes and 22-gauge fiberoptic temperature sensors were inserted through the anterior abdominal wall into the prostate. Two different freezing protocols were used: A) single (slow, mildly cold) freeze, passive thaw; B) two (fast, very cold) freeze/thaw cycles. Four dogs had a single lesion created using protocol B, and 13 dogs had 2 lesions – one each with protocol A&B. Ice formation was monitored with T1-weighted FSE. T2-weighted FSE images were acquired pre and post-procedure for 10 dogs (4 with one lesion & 6 with two lesions). T1-weighted 3D SPGR images were acquired post-procedure (for the 13 dogs with 2 lesions each), before & after administration of gadolinium contrast. All post-procedure imaging was completed within 2 hrs after end of cryoablation. Representative images of freezing, T2, T1-SPGR, CE are shown in Figure 1. ROIs were manually drawn on MR images for all measurements.

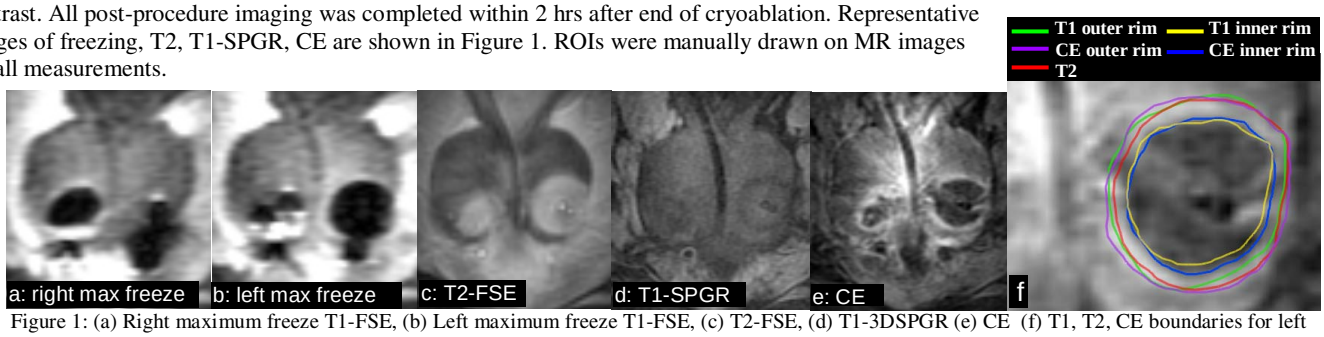

Figure 1: (a) Right maximum freeze T1-FSE, (b) Left maximum freeze T1-FSE, (c) T2-FSE, (d) T1-3DSPGR (e) CE (f) T1, T2, CE boundaries for left lesion superimposed on CE image. T1 & T2 lesion boundaries correspond well with CE lesion.

T2 Measurements: The change in T2 signal was calculated as the ratio of the signal measured in the frozen region to that in an unfrozen adjacent ROI, normalized by the signal in the same ROIs in a prefreeze image. A population-averaged generalized estimating equations (PA-GEE) regression of the T2 change on freeze protocol, freeze area, and time from maximum freeze, with subject as the clustering variable was performed (using 6 lesions for protocol A, and 10 for protocol B). The freeze area was measured as the fractional percentage of each lesion as compared to the total prostate area on the 2D slices.

T1 Measurements: The acute cryolesion appeared iso or slightly hypo-intense, surrounded by a dark rim on T1-weighted SPGR images. Multiple ROIs were selected at different positions within the dark rim. Signal intensity was measured on T1w & T2w images in the same ROIs, and normalized by unfrozen prostate signal intensity.
T1 & T2 lesion boundaries were manually outlined.

Results

In general, the outer boundary of the T1 & T2 lesion corresponded well with the outer boundary of the CE lesion (Figure 1f). The inner boundary of the T1 & CE lesions also were similar.

Upon adjusting for the effects of freeze area & time, the T2 signal change was greater for protocol B than for protocol A. For both protocols, T2 enhancement was higher for a smaller freeze area (Figure 2), and a longer time. The effects of area and time on T2 enhancement were smaller for protocol B than for protocol A. All these effects were significant at $p<0.001$.

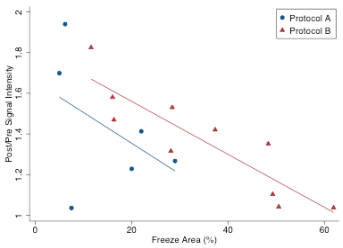

Figure2 : T2 enhancement as a function of freeze area, for protocols A&B.

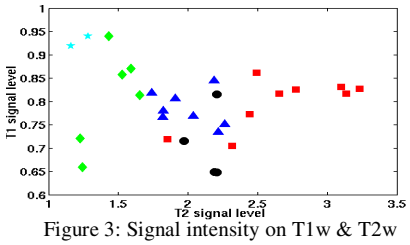

Figure 3: Signal intensity on T1w & T2w images, in the dark rim T1 lesion – normalized to unfrozen prostate. Each color is a different dog. The variation in T2 signal is much more than that in T1 signal.

The acute lesion on T1w images was observed only in 6 of the 13 dogs for protocol B, and on 4 dogs for protocol A. The conspicuity for the protocol B lesions was consistently higher than that for protocol A lesions. The T1w lesion was not present in all slices that showed the CE lesion. In some slices the dark rim was not present or did not completely surround it. Figure 3 plots the normalized signal intensity within the dark rim of T1-lesion, measured from T1-w & T2-w images, for protocol B. Each color represents a different dog. The variation on T2 between experiments is much greater than the variation on T1. Protocol A lesions (not plotted here) show a similar variation for T2, but the T1 rim was not as obvious.

Discussion

T2 signal enhances more for smaller cryo lesions. We hypothesize that this is caused by fluid accumulation into the cryolesion from injured microvessels that surround the lesion, and that in larger lesions the fluid is distributed over a larger volume, resulting in less T2 signal enhancement. The central region of the cryo lesion is hemorrhagic, which appears iso or hypo-intense on acute T1w images, while the dark rim could be a combination of hemorrhage and edema. Thus , in some cases, T1 & T2 imaging can provide lesion assessment after cryoablation.

References [1] Bouley D *et al* [2006], Proc. ISMRM p197, [2] Butts K *et al* [2003], JMRI 17:131:135
[3] Holbrook A *et al* [2007], Proc. ISMRM p3375, [4] Bradley W [1993], Radiology 189:15-26

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