Ice ball imaging during cryoablation of canine prostates: Contrast-enhanced MRI provides most accurate delineation of the acute necrotic zone

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Introduction

Cryoablation, i.e. tissue necrosis caused by freezing, is increasingly used for minimal invasive tumor cell destruction. Previous studies that used ultrasound for guidance of the ablation procedure concluded that ultrasound cannot reliably differentiate tissue necrosis from viable tumor cells during the ablation procedure, because of acoustic shadowing caused by the surface of the ice ball. Contrary to ultrasound, Magnetic Resonance Imaging (MRI) allows simultaneous imaging of the ice ball and surrounding tissue in 3 dimensions, and could be a valuable technique for monitoring cryoablation procedures.

Purpose

This study was designed to assess the accuracy of contrast-enhanced MRI for imaging ice ball size and visualization of the acute necrotic zone induced by cryoablation of canine prostates. Furthermore, we assessed the amount of tissue damage, measured as necrotic zone relative to total ice ball size, according to different freezing protocols.

Methods

Six adult male mixed breed dogs were preanesthetized, intubated, and placed in the 0.5T Signa open MRI system. A receive only endorectal coil was placed in the rectum. 17-gauge MRI compatible cryoablation probes (Galil Medical USA) and fiberoptic temperature sensors were inserted through the anterior abdominal wall into the prostate. Three different freezing protocols were used: A) single probe ablation, final temperature between -10°C and -40°C, one freeze/thaw cycle; B) single probe ablation, final temperature below -40°C, two freeze/thaw cycles; C) multiple probe ablation, final temperature between 0°C and -10°C, one freeze/thaw cycle. The size of the ice ball was evaluated with T1-weighted Fast Spin Echo (FSE) MR images and directly post-procedural with contrast-enhanced SPGR (SPoiled Gradient Recalled) T1-weighted images after administration of gadolinium. MR images were analyzed and manually segmented using ImageJ software for windows. Immediately following the procedure all dogs were sacrificed. Canine prostates were excised, stained with triphenyl tetrazolium chloride (TTC), photographed, prepared for hematoxylin and eosin (H&E) staining, and examined under a light microscope. MR imaging results were compared to pathology.

Results

A total of 12 cryolesions were bilaterally created in 6 canine prostates (Table 1). Mean maximum ice ball diameter, as reflected by low signal intensity (SI) zone on the T1 FSE imaging, was 439mm², 388mm², and 208mm² for freezing protocol A, B and C, respectively, and 356 mm² for the whole group. Direct post-procedural contrast-enhanced MRI (SPGR) typically showed a low SI (avascular) zone, centrally located within the frozen area, surrounded by a bright enhancing rim in all cases (n=12), see figure1. Based on physiology it is assumed that this area of low SI is the area corresponding to tissue necrosis. The mean area of low SI on contrast-enhanced MRI for all cases was 172 mm², whereas the mean area of tissue necrosis (including transition zone) on pathology was 169 mm². The mean area of necrosis relative to the mean size of the avascular zone of the ice ball on contrast-enhanced MRI for all cases was 169/172: 98%. This percentage was the highest for freezing protocol A and B (98%-100%) and the lowest for freezing protocol C (85%) indicating that C was the less optimal freezing protocol.

Dog	Freeze Protocol	Side	T1 FSE Low SI zone	SPGR Low SI zone	SPGR Low SI and high intensity rim zone	Pathology: Area of necrosis
1	A	Right	354 mm²	170 mm²	329 mm²	248 mm²
	B	Left	448 mm²	234 mm²	423 mm²	330 mm²
2	A	Right	379 mm²	197 mm²	413 mm²	168 mm²
	B	Left	437 mm²	153 mm²	270 mm²	187 mm²
3	A	Right	583 mm²	241 mm²	431 mm²	257 mm²
	B	Left	479 mm²	148 mm²	246 mm²	165 mm²
4	C	Right	291 mm²	284 mm²	442 mm²	178 mm²
	B	Left	308 mm²	305 mm²	436 mm²	218 mm²
5	C	Right	126 mm²	0 mm²	183 mm²	0 mm²
	B	Left	325 mm²	153 mm²	255 mm²	90 mm²
6	C	Right	208 mm²	12 mm²	161 mm²	73 mm²
	B	Left	329 mm²	172 mm²	314 mm²	113 mm²

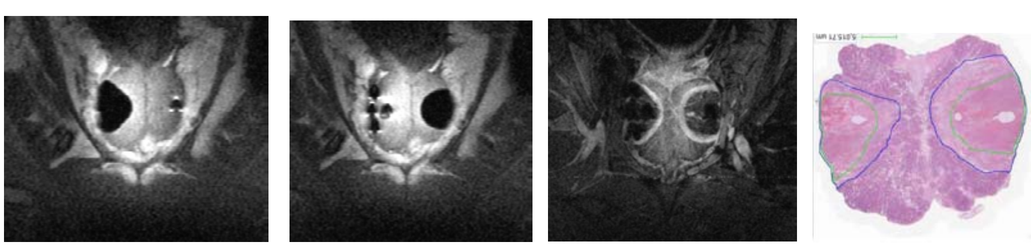

Fig. 1: Dog 4: A) Maximum ice ball size, reflected as low signal intensity zone on T1 FSE MRI, created by multiple probe ablation in the right side of the canine prostate. B) Maximum ice ball created by single probe ablation on the left side. C) Avascular zone within the ice ball, reflected as low signal intensity zone surrounding by a high signal intensity rim on contrast-enhanced (SPGR) T1-weighted imaging. D) Area of necrosis (green line) on pathology.

Conclusion

The edge of the ice ball created during cryoablation is clearly visualized on the T1 FSE sequence, but does not correlate to the area of tissue necrosis induced by the freezing. For imaging of tissue necrosis contrast-enhanced weighted imaging is more accurate. In this study 98% of the low signal intensity (avascular) zone on contrast-enhanced T1 SPGR series proved to be necrosis on pathology. The percentage of tissue necrosis relative to ice ball size was the lowest for freezing protocol C, indicating that at least temperatures below -10°C are needed, for successful cryoablation.