Diffusion-Weighted PROPELLER MRI for Tissue Selective Intra-Procedural Positioning of Percutaneous Biopsy Needles within Rabbit VX2 Liver Tumors

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INTRODUCTION

Percutaneous needle biopsy currently serves as a conclusive diagnostic procedure for liver lesion characterization. MRI can be used for intra-procedural guidance during percutaneous liver-directed interventions (1). Optimal targeting of viable tumor tissues is critical during biopsy procedures. Viable tissue is required for accurate histological confirmation of malignancy. Sampling errors may result when using conventional anatomic and/or contrast-enhanced images for intra-procedural guidance. These sampling errors may lead to insufficient material for diagnosis and require additional tissue sampling. Diffusion-weighted MRI (DWI) is a promising method for *in vivo* differentiation between viable tumor tissues and tumor necrosis (based upon differences in tissue water mobility) (2,3). TSE-based DW-PROPELLER techniques (4) should be less sensitive to susceptibility-induced field inhomogeneities near interventional devices. In this study, we tested the hypothesis that intra-procedural DW-PROPELLER imaging can be used to selectively position biopsy needles within either viable or necrotic regions in VX2 rabbit liver tumors.

METHODS **MR-Guided Percutaneous Procedures** All percutaneous procedures and imaging experiments were performed with VX2 rabbits (N=6) positioned within a 1.5T clinical scanner (Siemens Espree) using a four-channel head coil. T2W-PROPELLER images were acquired at contiguous axial slice positions covering the entire liver volume. Next, baseline DW-PROPELLER images were acquired at the same slice positions: FOV = 200×200 mm^2, TR/TE = 3000/77ms, matrix = 192×192, TH=3.0 mm, ETL = 21, blade # = 60, BW = 789 Hz/pixel, b-value = 0, 534 and 866 s/mm^2. After baseline imaging, an MR-compatible 22 gauge aspiration biopsy needle (E-Z-EM Inc.,NY,USA) was inserted percutaneously into the selected rabbit liver tumor. Next, serial T2W and DW-PROPELLER (b-value = 534 s/mm^2) imaging was performed with needle position iteratively adjusted between measurements to target either viable, necrotic, or intermediate border tissue regions. At final needle position, for each selected tissue type, DW-PROPELLER images at all b-values were acquired. For comparison purposes, we acquired a set of single-shot DW-EPI images. Prior to biopsy procedures we also acquired contrast enhanced (CE)-T1W-GRE images. At final needle location, a solution with 40-120μm spherical polyvinyl alcohol (PVA) particles (blue color, Beadblock; Terumo Medical) was injected through the needle shell to allow confirmation of needle tip position at necropsy. **Histopathology Analysis** Rabbit livers were sliced in the axial plane to correspond to the MR image planes. Tumor slices for which clusters of blue beads were visibly observed were selected for H&E staining and examination by attending surgical pathologist (>10yrs experience). Within regions surrounding these needle tip positions, H&E cell morphology characteristics were used to qualitatively estimate tissue necrotic fraction. On DW-PROPELLER images, a small ROI (10-15 mm^2) encompassing the needle tip was selected. Each of these ROIs was transferred to the corresponding baseline DW-PROPELLER image series (without needle in place) and the ADC values within these ROIs were calculated. Mean ADC within the ROI encompassing the needle tip was compared to the corresponding qualitative necrotic fraction estimate (H&E histopathology). For these measurements, the Pearson's correlation coefficient was calculated with $p < 0.05$ considered statistically significant.

RESULTS In **Fig.1-3**, DW-PROPELLER images clearly depicted intra-tumoral tissue heterogeneity, particularly for those larger VX2 tumors consisting of viable peripheral regions surrounding a central necrotic core. The MRI compatible needles were clearly visualized in each DW image as signal voids along the needle track. At a total of 23 needle positions within 15 VX2 tumors, mean ADC values within the ROIs compassing the needle tips were compared with the percentage of tumor necrosis qualitatively assessed at histopathology. DW-PROPELLER ADC measurements were highly correlated with these histopathology necrotic fraction measurements ($r = 0.926$, $p < 0.0001$). CE images qualitatively demonstrated less intra-tumoral heterogeneity than corresponding DW images and reduced regional areas of enhancement compared to restricted diffusion, high-signal intensity areas within corresponding DW images.

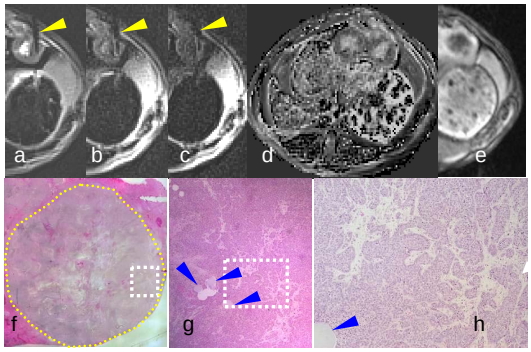

Figure 1. DW-PROPELLER images (**a-c:** b-value = 0, 534 and 866s/mm^2) with needle (yellow arrow heads) positioned to target the viable region. ADC map (**d**) reconstructed from baseline DW images demonstrated decreased water mobility at the position of needle placement. CE image (**e**) demonstrated perfusion of the tumor periphery. Overview H&E image (×25 magnification) (**f**) of the tumor (yellow contour line at tumor border) shows central necrotic core with viable tumor periphery. Magnified image (**g**) from inset within (**f**: white dashed-box) shows the location of the injected beads (blue arrow heads) which served as our *ex vivo* reference for needle tip position. Tumor tissues within the region of bead deposition (×100 magnification image **h** from inset position within **g**) were classified as 95% viable at histopathology.

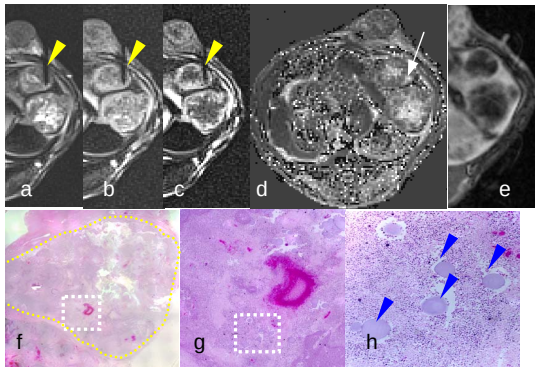

Figure 2. DW-PROPELLER images (**a-c:** b-value = 0, 534 and 866 s/mm^2) were acquired with needle (yellow arrow heads) positioned to target a small necrotic region located within the tumor periphery. The corresponding baseline ADC map demonstrated increased ADC measurements at the position of needle placement (white arrow) compared to surrounding viable tissues (**d**). CE T1W image (**e**). Overview H&E pathology image (×25 magnification) (**f**) of the tumor (yellow contour line at lesion border) shows intra-tumoral heterogeneous distribution of viable and necrotic tumor tissues. Magnified image (**g**) from inset within ×25 overview image (white dashed-box in **f**) shows the location of the injected beads. Tumor tissues within the region of bead deposition (blue arrow heads, ×100 magnification image **h** from inset position within **g**) were classified as 100% tumor necrosis at histopathology.

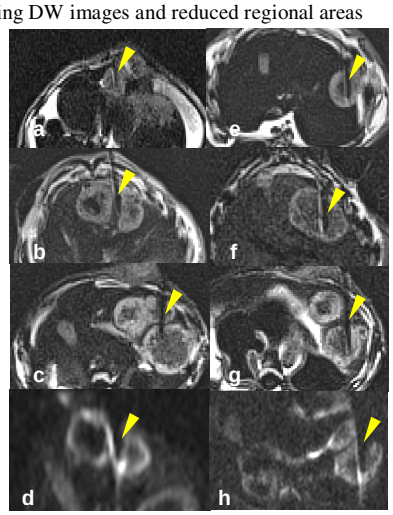

Figure 3. DW-PROPELLER images (b= 866 s/mm^2) (**a-c** and **e-g**) acquired in 6 animals. Tumor tissues around the needle tip positions were characterized as 80-90% viable (**a, b**), 50% viable (**c, e**) and 100% necrotic (**f, g**) at histopathology. Severe image distortion within two representative single-shot DW-EPI images (b= 850 s/mm^2) (**d**, **h**), acquired at the same slice positions as **b** and **g**, obscured depiction of hepatic and tumor anatomy adjacent to needle positions.

CONCLUSIONS We have demonstrated the feasibility of using DW-PROPELLER MRI to guide biopsy needle placement to selectively target viable tissues within VX2 rabbit liver tumors. DW-PROPELLER is a promising method to optimize placement of percutaneous devices during interventional procedures. Future translational studies should evaluate the use of the DW-PROPELLER techniques for functional targeting during MR-guided percutaneous procedures in liver cancer patients.

References: [1]. Schmidt AJ, et al. J Vasc Interv Radiol 1999;10(10):1323-1329. [2] Lyng H, MRM 2000;43(6):828-836. [3] Deng J. JMRI. 2008;27(5):1069-76. [4] Pipe JG, MRM 1999;42:963-969