High Resolution *Ex Vivo* MRI of Prostate Specimen, Correlation with Whole-Mount Histology and *In Vivo* MRI

C. R. Haney[1], X. Fan[1], G. Agrawal[1], C. A. Pelizzari[2], G. S. Karczmar[1], J. Bakst[3], T. Antic[3], S. E. Eggener[4], and A. Oto[1]
[1]Radiology, University of Chicago, Chicago, Illinois, United States, [2]Radiation & Cellular Oncology, University of Chicago, Chicago, Illinois, United States,
[3]Pathology, University of Chicago, Chicago, Illinois, United States, [4]Urology/Surgery, University of Chicago, Chicago, Illinois, United States

Introduction: We hypothesize that high resolution MRI of *ex vivo* prostate specimen can improve identification of cancer. We report preliminary results in correlating *ex vivo* MRI of prostate specimen with whole-mount histology and *in vivo* MRI. Eight excised prostate specimens were imaged immediately after surgery with a Bruker 9.4T scanner. Axial fast spin echo MRI images, along with diffusion weighted imaging (DWI) and T2-maps, were correlated with whole-mount histology and *in vivo* MRI. Although registration of the *ex vivo* and *in vivo* images remains a challenge, the *ex vivo* images provide useful information for diagnosing cancer. High resolution *ex vivo* T2-weighted MRI showed greater detail and contrast-to-noise ratio than clinical *in vivo* MRI. *Ex vivo* MRI can guide development of improved *in vivo* protocols and serve as a 'bridge' to correlation of *in vivo* imaging with histology. The results to date suggest that high resolution T2-weighted *ex vivo* MRI differentiates between carcinoma and benign prostatic hyperplasia (BPH).

Methods: To date, eight patients (average age 64 years) scheduled for radical prostatectomy were recruited under an approved IRB protocol. Pre-operative endorectal prostate MRI was performed at 1.5 T. The specimen size was typically 5 to 7 cm in transverse and 3 to 4 cm in the anteroposterior dimension. Axial high resolution fast spin echo T2 weighted images (TR/TEequivalent = 5000/40 ms, in-plane resolution = ~130 μm, array size = 512×256, slice thickness = 1 mm, slice gap = 1 mm, and number of averages = 2) were acquired to register with histology as the orientation for both MRI and histology was nearly axial. This scan was also used to guide the region of interest for DWI and T2 map imaging. Axial DWI (TR/TE = 4000/27.7 ms, array size = 256×128, in-plane resolution = ~200 μm, slice thickness = 2 mm, slice gap = 1 mm, b-value = 0, 1000, and 3000 s/mm^2) was acquired to identify any suspicious regions. For the same geometry as in DWI, multiple spin echo T2-weighted images (TR = 5000 ms, number of echo = 16, smallest TE = 12.5 ms) were acquired to generate the T2 maps. After *ex vivo* imaging, the specimen was fixed with formalin and was sliced accurately into 4-mm thick slices, then scanned with a desktop optical scanner. The 3D stack of the optical scans facilitated assembly of the 3D stack of histology scans and served as a 'bridge' to the *ex vivo* MRI. Plastimatch was used to warp the *ex vivo* images to the *in vivo* MRI.

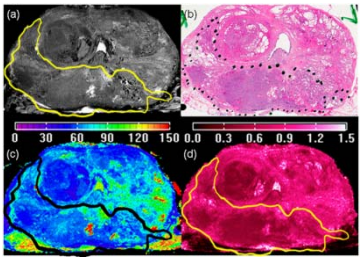

Figure 1 Example from a 71 year old patient, (a) *ex vivo* T2 weighted MRI prostate images, (b) approximately corresponding histology slice, (c) *ex vivo* T2 map, and (d) *ex vivo* ADC map. On histology slide cancer identified by the pathologist shown as a dotted line is overlaid on the *ex vivo* MRI.

Results: Preliminary results suggest that high resolution *ex vivo* MRI helps identify tumor boundary in addition to facilitating registration of *in vivo* MRI and histology. Figure 1 shows the close correlation between the *ex vivo* images with histology without registration and warping. Cancers were generally characterized by low apparent diffusion coefficient (ADC) (~40×10-3 mm^2/s) and T2 (~50 ms) values. However, low ADC and T2 values were not exclusive to cancers. Simple affine registration cannot overcome deformation of the prostate by the bladder and endorectal coil. However, thin plate spline warping is able to register the *in vivo* to *ex vivo* and histology. Figure 2 is an example of the results of warping the *ex vivo* image to match the corresponding *in vivo* image. The *in vivo* MRI requires extensive warping due to the deformation of the prostate by the bladder and endorectal coil. The results demonstrate the possibility to correlate *in vivo*, *ex vivo* MRI, and histology.

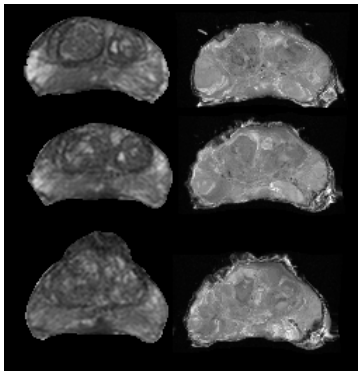

Figure 2 Registration with warping using Plastimatch. Left column: *in vivo* T2 weighted MRI. Right column: warped *ex vivo* T2 weighted MRI. Note bend from endorectal coil warped correctly on *ex vivo* images.

Conclusion: High resolution MRI not only facilitates registration of histology to *in vivo* MRI but also provides more information without damaging the sample. Deformation of the prostate from the endorectal coil and bladder along with shrinkage due to fixation required advanced warping techniques. The ability to compare non-invasive *in vivo* imaging to histology, accurately, will further the discovery of image based biomarkers. Higher resolution *ex vivo* MRI will help optimize *in vivo* MRI.