Purpose: Optimize and evaluate a biomechanical model-based deformable image registration algorithm incorporating specimen-specific changes in material properties for correlating histology of clinical prostatectomy specimens with invivo MRI.

Methods: An in-house biomechanical model-based deformable registration based on finite element modeling was developed for accurate correlative pathology for clinical prostatectomy. Five image sets were acquired for 4 prostatectomy patients: 1) invivo T2 MRI, 2) exvivo fresh (before fixation) T2 MR, 3) exvivo fixed (after fixation), 4) digital photographs of gross slices after sectioning, and 5) digital whole-mount histology images of the slices. A 2D landmark based deformable registration technique is used to accurately reconstruct 3D histology volume based on fixed and gross image sets. A 3-step deformable registration based on biomechanics calculates the transformations between histology and fixed, fixed and fresh, and fresh and invivo. Magnetic Resonance Elastography performed on the exvivo tissue provided a specimen specific element-based Young's modulus map for the fresh and fixed tissue accounting for changes due to fixation. The accuracy of the algorithm was quantified by identifying naturally occurring fiducials in each image and evaluating the Dice overlap index of contoured regions within the prostate. The accuracy was compared to a rigid registration technique.

Results:The average absolute error based on fiducial points in Left-Right (LR), Anterior-Posterior (AP), Superior-Inferior (SI) directions was 1.3, 1.1, and 1.0 respectively compared to 1.7 (LR), 1.3 (AP), and 1.3 (SI) [mm] achieved with rigid registration. The maximum absolute error was also reduced from 5.4 with rigid to 3.6 mm with deformable registration. A DICE index of 0.67 was achieved using the deformable registration, compared to 0.49 with rigid registration.

Conclusions: A biomechanical model-based deformable registration algorithm which incorporates tissue specific changes in material properties has been developed and evaluated on prostatectomy samples, showing marked improvement over rigid registration.