Quantitative and Radiologic Evaluation of the Patient-specific MR-based Molds

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Introduction: MRI is the current modality of choice in the detection and localization of prostate cancer. In order to increase the efficacy of MRI, it is necessary to correlate and validate those results with histology. This is not straightforward since the prostate is a deformable organ and it often deforms during imaging and after prostatectomy. Recently, Patient-Specific MR-based Mold (PSMRM) was used to process radical prostatectomy specimens so that the tissue blocks obtained were uniformly thick and parallel to the *in vivo* MR slices[1]. Studies have shown that the size of prostate can change over time due to benign prostatic hyperplasia (BPH)[2]. Additionally, the shrinkage and toughening of tissues after fixation[3] could affect the fit of the specimen in the mold. Hence, it is necessary to provide quantitative and radiologic evaluation of the PSMRM for processing the specimen. In this study, we correlate *ex vivo* MRI of the specimen with the *in vivo* MR images to determine the effectiveness of the PSMRM.

Methods and Materials: The patients, who later underwent radical prostatectomy, were enrolled in a single institution study that has been approved by the local institutional review board. This study included 12 patients, and prior to surgery, each patient was scanned on a 3.0 T whole-body MRI system (Achieva, Philips Healthcare, Best, NL) using an endorectal coil (BPX-30, Medrad, Pittsburgh, PA) combined with the 16-channel anterior half of an InVivo SENSE cardiac coil. The endorectal coil was placed into the rectum and the balloon around the coil was distended using a liquid perfluorocarbon (Fluorinert FC-770, 3M, St. Paul, MN) to a volume of approximately 50 ml to avoid susceptibility artifacts caused by air in the balloon. Multislice T2-weighted turbo spin-echo (TSE) images of the entire prostate were obtained in three orthogonal planes (sagittal, axial, and coronal) at a scan resolution of 0.461 x 0.598 x 3.0 mm^3, field of view (FOV), 140 mm; acquisition matrix, 234 x 304; TR/TE, 8869/120 ms; flip angle, 90°; slice thickness, 3 mm without gaps; image reconstruction, 512x512. Contour lines were drawn along the prostate capsule on the MR images obtained in sagittal, axial, and coronal plane using MIPAV (http://mipav.cit.nih.gov/). The contour lines from all the MR images (three views) were converted into points and merged together. A high resolution prostate surface is obtained using the Meshlab (http://meshlab.sourceforge.net/). A PSMRM was created using the high-resolution prostate model[1]. *In vivo* volume and surface area of the prostate is obtained from the high-resolution prostate model in SolidWorks. The radical prostatectomy specimen, which is fixed in formalin overnight, is placed in the mold after amputating the seminal vesicles. TSE images of the specimen in the mold were obtained using the Sense Flex-M coil in three orthogonal planes (sagittal, axial, and coronal) at a scan resolution of 0.461 x 0.438 x 3.0 mm^3, acquisition matrix, 320 x 304; TR/TE, 7000/65 ms; other parameter remained same as *in vivo images*. The volume of the specimen is obtained using the approach used for *in vivo* images i.e. a high resolution prostate model from *ex vivo images*. To provide the radiological evaluation an experienced radiologist evaluated both *in vivo* and *ex vivo* MR images slice by slice for visible anatomical structures such as lobes, cysts, and urethra.

Results & Discussion: Volume and surface area of the prostate capsule on in vivo and ex vivo MRI is provided in Table 1. The average interval between MRI and the surgery was around 2.67 months. The average relative difference in volume and surface area was 9% and 7% respectively. Except for the case 2 and 7, the relative difference in the volume was less than 15%. The Pearson correlation coefficient between % difference in volume and PSA was -0.25 indicating that there is no statistical significant correlation between tissue shrinkage and PSA condition. The paired t-test showed that there is a statistically significant difference between *in vivo* and *ex vivo* volume ($p = 0.0026$, $\alpha < 0.05$) and the surface area ($p = 0.00055$, $\alpha < 0.05$). *In vivo* and *ex vivo* images were compared on slice by slice basis by a radiologist for all the cases. For two cases radiology evaluation could not be performed well because it was observed that urethra marker in the mold did not correlate well with that of the specimen because of human error. The radiologist could easily correlate the *in vivo* and *ex vivo* for various structures for other 9 patients, while one case (no. 12) was challenging because insufficient landmarks throughout the prostate. This radiologic evaluation of PSMRM substantiates the fact the tissue blocks would in-fact correlate with the *in vivo* MR slices when the specimen has a good fit inside the mold as can be observed in figure 1. However, when there is too much shrinkage tissue blocks obtained may not have one to one correspondence with *in vivo* MR slices. In figure 2, radiologist could correlate the *in vivo* and *ex vivo* MR images for different structure but the slices were off by one MR slice (3mm) because of tissue shrinkage. Thus this factor should be taken into account while correlating it with histology.

Table 1: Statistics for the patient population

Case No	Interval (month)	Age (yrs)	Volume cc		% Diff	Surface Area sq cm		% Diff	PSA
			In vivo	*Ex vivo*		*In vivo*	*Ex vivo*		
1	5	60	36.30	35.10	3.31	58.02	56.17	3.20	8.6
2	4.5	69	51.75	39.70	23.28	72.06	61.34	14.88	5.5
3	2	63	43.89	39.98	8.91	65.96	60.80	7.83	5.8
4	2	60	47.35	45.98	2.90	69.87	67.81	2.94	4.0
5	2	58	46.94	43.37	7.61	68.30	65.51	4.09	3.9
6	2	63	48.07	46.72	2.80	67.80	66.34	2.15	5.7
7	3	58	47.80	35.53	25.68	68.55	55.34	19.27	7.7
8	2	54	67.46	58.74	12.93	85.27	78.40	8.06	2.4
9	1.5	59	40.99	40.13	2.10	63.03	60.67	3.74	35.9
10	1	58	74.41	71.50	3.91	92.31	88.42	4.21	8.1
11	2	58	43.71	39.49	9.64	66.45	60.49	8.96	1.7
12	5	65	43.51	40.89	6.03	67.13	62.27	7.23	3.5
mean	2.67	60.55	49.35	44.76	9.09	70.40	65.30	7.21	7.73

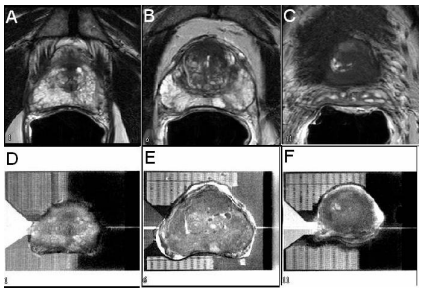

Figure 1. Good correlation between *in vivo* (A-C) and *ex vivo* MR images for case 9, tissue shrinkage is mininum.

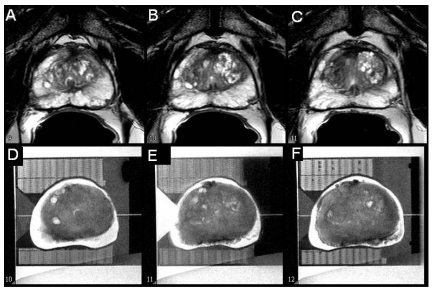

Figure 2. Correlation between *in vivo* (A-C) and *ex vivo* MR images for case 7, the tissue shrinkage is maximum

Reference: (1) V. Shah, *et. al.*, Rev. Sci. Instrum. **80**, 104301 (2009). (2) J. C. Nickel, Urol. Clin. North Am. **35**, 109 (2008). (3) S. Jonmarker, A. Valdman, A. Lindberg, M. Hellstrom, and L. Egevad,Virchows Arch. **449**, 297 (2006).