A MRI-based Virtual Cystoscopy System for Evaluation of the Entire Bladder

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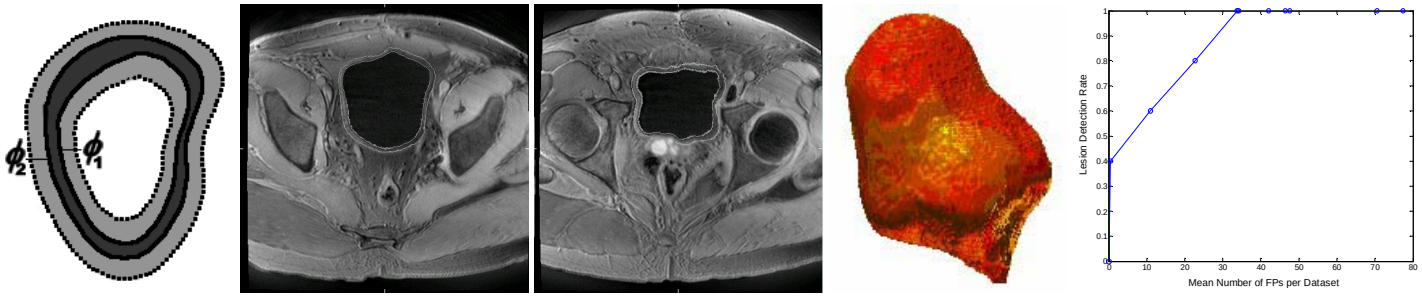
Introduction: Bladder cancer becomes the fifth leading cause of cancer-related deaths in the United States, primarily in older men with a 3:1 ratio of men to women, due to its rapid increase (as high as 36% within a decade) [1]. Over 56,000 cases of bladder carcinoma and more than 12,000 deaths were reported in 2002 [2]. Bladder tumor is difficult to manage because of its high recurrence rate after resection (as high as 80%) [1, 2]. Therefore, it is essential to detect bladder abnormalities in a non-invasive and convenience manner, especially for follow-ups of resection. A common test for bladder tumor is urine dipsticks measuring the peroxidase activity of hemoglobin. It is sensitive but has a low specificity (approximately 70%). Computed tomography has been explored to detect bladder abnormality [3], where the urine has to be either tagged by intravenous injection or empted with replacement of air through a catheter. The invasive nature deems to be impractical in addition to the associated X-rat radiation. Because of the significant difference in T1 and T2 relaxations between urine and bladder wall, magnetic resonance imaging (MRI) has the potential to provide a non-invasive means for evaluation of the entire bladder [4]. This paper presents a MRI-based virtual cystocopy system which extracts the bladder wall from a T1 volume image of the bladder, analyzes the image texture of the extracted wall, and detects the patches where abnormalities are highly likely present for reviewers' assessment, i.e., a computer-aided detection (CAD) of abnormalities.

Methods: In order to minimize the partial volume effect (PVE) between the urine and bladder wall, T1 weighted images were acquired as the primary information for the detection purpose, where the signal of urine is suppressed and the PVE goes from the wall into the lumen and has less impact on the wall as compared to T2 weighted images, where the signal of urine is enhanced and the PVE goes from the lumen into the wall and would bury small pathological changes on the mucosa. Two T1 scans were acquired after the patient voiding the bladder and taking a cup of water. One scan was at the middle stage of half-filled bladder and the other was at the final stage of fully-filled bladder. The protocol on a Philips 1.5T Edge whole-body scanner with body coil as the transceiver includes: 3DFFE-SPIR CLEAR sequence, 1.5mm slice thickness, 10^o flip angle, 448x448 image size with T_R =4.6666ms and T_E =2.2766ms. Each of the T1 volume image was segmented by a hybrid method which searches an inner border of the bladder by level-set strategy starting from a group of voxels with lowest intensity in the image. From the inner border, an enlarged version was obtained by the same level-set strategy with a different energy function. Fig. 1(a) is a 2-D presentation. The obtained wall was then dilated for a sufficient large layer, which was further quantified by PV segmentation. Each voxel inside the dilated layer after the PV segmentation contains the percentages of three tissue types: urine, wall and mixture of fat/muscle (outside the wall). Those voxels with small wall percentages of less than 5% were ignored and the remaining voxels represent the bladder wall. Two examples of dilated layers are shown in Fig. 1(b) and 1(c). An example of extracted bladder is shown in Fig. 1(d).



(a) (b) (c) (d) (e)

Results: The presented system was tested on ten MR patient bladder scans with two tumors greater than 10 mm, one of 4 mm, and two less than 3 mm. The FROC curve for the automatic CAD of the tumors is shown in Fig. 1(e). The likelihood of detecting tumors equal or greater than 4 mm is satisfactorily. The detection sensitivity reaches 100 % with less than 35 false positives per patient scan.

Discussion: Although early detection of bladder cancer (tumor less than 3 mm) remains a challenging task by current clinical MRI scanners with 1.5 mm voxel resolution, the presented MRI-virtual cystoscopy system has demonstrated the potential for evaluation of tumor recurrence, which would otherwise require the patient to follow-up with fiberoptic cystoscopy every three to six months after tumor resection. Early detection would be feasible with improvement of MRI spatial resolution.

References: [1] D. Lamm, et al., "Bladder cancer," *CA Cancer J. Clin.*, **46**: 93-112, 1996. [2] A. Jemal, et al., "Cancer statistics," *CA Cancer J. Clin.*, **52**: 23-47, 2002. [3] J. Fielding, et al., "Tumor detection by virtual cystoscopy with color mapping of bladder wall thickness", J. Urology, **167**: 559-562, 2002. [4] Z. Liang, et al., "Feasibility studies on extracting bladder wall from MR images for virtual cystoscopy", *ISMRM*, **3**: 2204, 1999.