# Quantification of intra-procedural gland motion during transperineal MRI-guided prostate biopsy

Andriy Fedorov[1], Kemal Tuncali[1], Tobias Penzkofer[1,2], Junichi Tokuda[1], Sang-Eun Song[1], Nobuhiko Hata[1], and Clare Tempany[1]

[1]*Radiology, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, United States,* [2]*Department of Diagnostic and Interventional Radiology, RWTH Aachen University Hospital, Aachen, North Rhine-Westphalia, Germany*

**Target audience** Interventional radiologists, researchers in medical image analysis and interventional image-guided robotics.

**Purpose** Magnetic Resonance Imaging (MRI) is a superior modality for detection, staging, localization and characterization of Prostate cancer (PCa) [1]. Interventional applications of MRI in PCa management include MRI-guided core needle biopsy that can be recommended for some patient populations, and may lead to improved accuracy of cancer detection. Although MRI enables targeted sampling of the tissue from the suspected cancer regions, precise needle placement is challenging due to several factors that include motion of the patient and prostate gland during the course of the procedure, which may introduce discrepancies with respect to the biopsy plan established in the beginning of the procedure. The objective of this work is to retrospectively quantify the extent of prostate gland motion during transperineal MRI-guided prostate biopsy using image registration technology.

**Methods** *Image acquisition* MR images were collected in the course of the MRI-guided transperineal prostate biopsies (N=40), all of which were conducted in a wide bore Siemens Magnetom Verio 3T MR scanner. The patients were immobilized on the table top with velcro wrap and sedated. Imaging studies for each patient used a combination of body coil and pelvic array receiver elements and included (1) axial FRFSE T2w MRI (voxel size 0.5×0.5×3 mm, imaging time ~4 min) obtained in the beginning of the biopsy procedure for the purposes of target identification (planning scan) and (2) a series of lower resolution T2w MRI (voxel size 0.75×0.75×3 mm, imaging time ~1 min) collected after needle placement to visually assess targeting accuracy (needle confirmation scan). Prostate gland was contoured manually in the higher resolution T2w scan as part of intra-procedural workflow. *Image processing* Custom deformable image registration strategy was based on the earlier developed methodology and 3D Slicer software [2,3]. Imaging studies collected for each patient were post-processed to register planning T2w scan to each of the needle confirmation scans. In each case registration was performed separately for the prostate region of interest and for the pelvic bone structures to independently quantify the motion of the prostate and the pelvis. Registration accuracy was confirmed by visual inspection of each image pair. Improvement in the alignment of prostate gland was quantified by comparing the Dice overlap coefficient between the segmentations of the prostate gland in the planning T2w scan and in the final needle confirmation image, before and after registration. *Prostate motion characterization* Coordinates of the centroid of the prostate gland were automatically calculated for each patient. We summarized patient-specific prostate motion by applying the registration-estimated transformations to the prostate gland centroids and recording centroid translation in antero-posterior, lateral and longitudinal directions. Prostate motion was summarized separately using the pelvis and gland ROI based registration results to assess agreement of the pelvic and prostate gland motion. 3-dimensional motion and axial in-plane 2-dimensional motion were summarized separately, since in-plane motion creates greater potential for targeting errors in the template-guided transperineal biopsy.

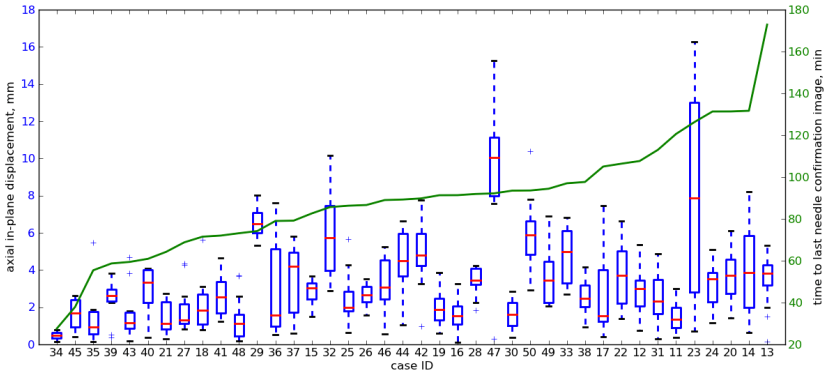


***Figure 1 (above)**: Summary of the in-plane motion of the prostate gland centroid as recovered by deformable registration of the prostate gland ROI (median, lower and upper quartiles (bottom and top 25% of the data) and the extreme values within the 1.5 × inter-quartile range)), ordered by the time between the planning and the final needle confirmation scans (time corresponds to the green line, axis on the right).*

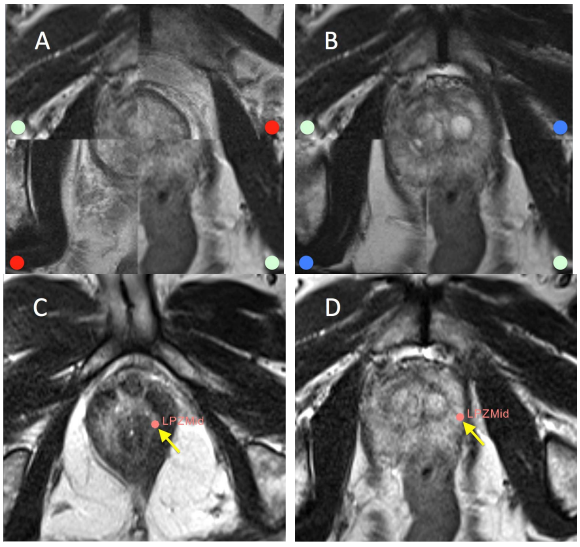


***Figure 2 (right)**: Illustration of a prostate ROI registration result. A and B: checkerboard of the needle confirmation (segments marked with light green circles), planning (red) and registered (blue) images. C and D: planned target (arrow) before and after prostate motion compensation.*

**Results** The total of 538 needle confirmation images were used in the evaluation. Mean time between the planning scan and the final needle confirmation image was 90 min (range 28-172 min). Registration results were inspected visually and improved alignment of the anatomical structures between the registered planning scan and the needle confirmation images was confirmed in all cases. Assessment of the gland segmentation overlap before and after registration for the final needle confirmation image showed improved DSC in 38/40 cases, with the average improvement by 0.18 ($p<0.0001$). Mean magnitude of the prostate gland centroid motion was 8.7 mm (range: 0.2-34.7 mm) in 3d, and 3.4 (0.1-16.3 mm) in 2d. In 102/538 cases (18.9%) 2d motion magnitude exceeded 4.9 mm (the sphere radius corresponding to a clinically significant tumor volume of 0.5 cc). Mean discrepancy between the locations of the prostate gland estimated by registration that used pelvis ROI (rigid) compared to gland ROI was 3.8 mm (0-18.8 mm).

**Discussion** Our results indicate that intra-procedural prostate motion can lead to significant discrepancies between the planned and true location of the biopsy target. Major component of prostate motion appears to be in the longitudinal direction, however in-plane motion is significant and could potentially lead to a missed target in 18% of the cases (the accurate estimate depends on the true lesion volume). Intra-procedural imaging enables detection of prostate motion and correction of the needle placement, relying on either the visual estimation of placement error, or on the automatic registration methods. We observed a significant discrepancy in the location of prostate gland as estimated by using pelvis-based registration as opposed to gland ROI based approach, which agrees with earlier studies [4].

**Conclusions** Intra-procedural motion and deformation of the prostate may lead to increased targeting errors during image-guided biopsy procedures. Application of intra-procedural registration is recommended for intra-procedural quantification and recovery of target motion. As opposed to gland-based registration, approaches that rely on bulk pelvic motion to estimate prostate gland motion and deformation are not sufficient due to the large discrepancy in the recovered gland location.

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**References** [1] 1. Heijmink et al. Acta oncologica. 2011, 50:25–38. [2] Fedorov et al. JMRI, 2012, 36(4):987-92. [3] http://slicer.org [4] Kupelian et al. Int J Rad Onc Biol Phys. 2007, 67(4):1088–98.