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Validation Of MRI To US Registration For Focal Hdr Prostate Brachytherapy Treatment

Author Block: Eric Poulin, PhD^{1,2}, Karim Boudam, MSc², Csaba Pinter, MSc³, Samuel Kadoury, PhD⁴, Andras Lasso, PhD³, Gabor Fichtinger, PhD³, Cynthia Ménard, MD².

¹Radio-Oncologie, CHU de Québec, Québec, QC, Canada, ²Radio-Oncologie, CHUM, Montréal, QC, Canada, ³School of computing, Queen's University, Kingston, ON, Canada, ⁴Computer engineering, Polytechnique Montréal, Montréal, QC, Canada.

Abstract:

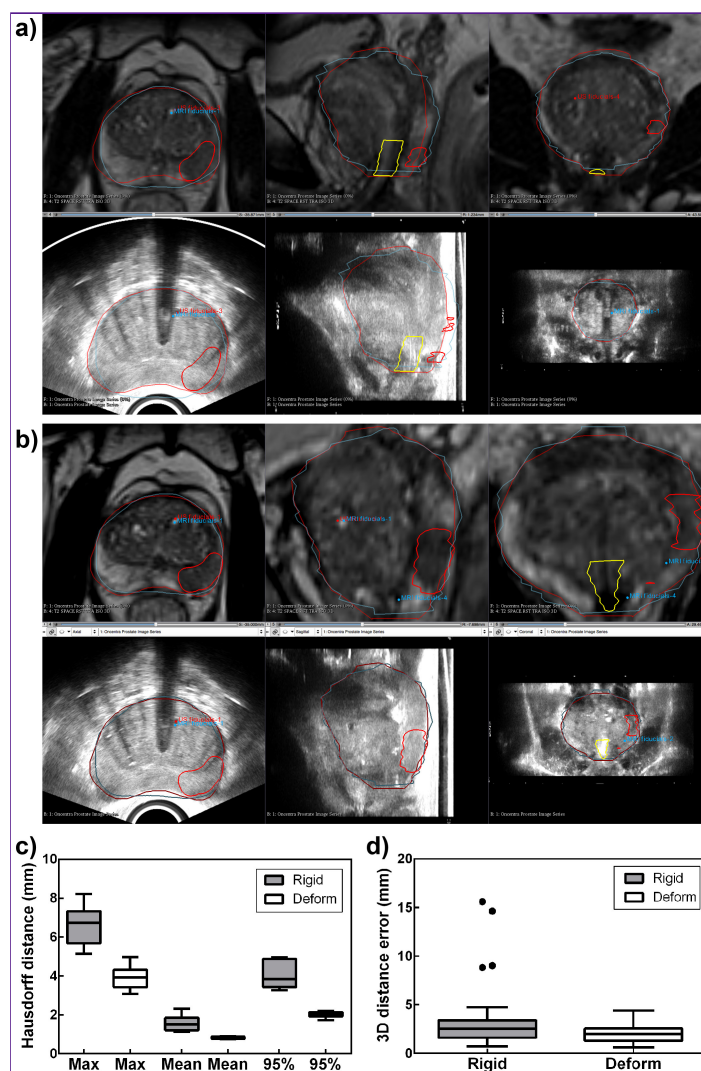
Purpose: High dose rate (HDR) prostate brachytherapy can achieve long-term disease control. Multiparametric Magnetic Resonance Imaging (mpMRI) allows identification of gross tumor (GTV) in order to boost or target lesions. However, a significant number of clinics are using ultrasound (US) as their planning imaging modality due to its low cost and real time capability; but can't identify the position of the GTV. Therefore, a registration is needed between mpMRI and US images to accurately position the GTV. The goal of the study was to develop and validate a new 3D Slicer MRI to US registration module for focal HDR prostate brachytherapy treatment.

Materials and Methods: In this study, eleven patients with prostate cancer who underwent HDR brachytherapy, with lesions visible on mpMRI, were selected for the validation. T2-weighted 3D variable-flip-angle TSE images with 1mm isotropic voxel and diffusion weighted images were acquired on a 1.5T SIEMENS Magnetom, using surface coils, for prostate and GTV contouring. 3D US images, with 0.5 mm thick slice, were obtained with Oncentra Prostate (OcP) system using BK Flex Focus 400. The new module is incorporated in 3D Slicer and is using SlicerProstate and SlicerRT extensions, with the validated BRAINS method, to perform rigid and deformable registration. The module allows DICOM-RT structures to be imported while contours transformed from rigid and deformable transformations can be exported in RT structures for direct use in treatment planning system (TPS). The rigid registration is performed on both MRI and US prostate surface meshes. The deformable B-spline registration is performed after an initial rigid registration to elastically align the binary 3D label maps. To validate the module, prostate contours were obtained by an experience Radiation Oncologist on both MRI and US images; common points were also identified on US and MRI registered images. Dice and Hausdorff indices were obtained to validate the registration.

In addition, volumes were compared and Target Registration Errors (TRE) were calculated for the centroid and common points. A paired t-test was used to compare the methods.

Results: The complete registration step is performed in a clinically acceptable time of less than 5 minutes. RT structures were successively imported into OcP TPS, a requirement for brachytherapy procedures. The module offers Dice and Hausdorff metric with TRE calculation to assess the accuracy of the registration. Fig. 1 shows a representative registration between MRI (blue) and US (red) contours for a) rigid and b) deformable registration. The deformable registration allows a better representation of the prostate at the time of brachytherapy as it can correct the US endorectal probe deformation. Dice indices were found to be 0.93 ± 0.01 and 0.87 ± 0.05 for the deformable and rigid registration, respectively. Fig. 1 shows c) maximum, mean and 95% confidence interval Hausdorff value for rigid and deformable registration. Rigid and deform MRI volumes (39.6 ± 12.1 , 39.4 ± 12.2 cm³) were not statistically different ($p > 0.05$) from reference US volumes (38.6 ± 11.9 cm³). TRE between centroid position was 2.10 ± 0.98 and 0.37 ± 0.14 mm for the rigid and deformable registration, respectively. Fig. 1 shows d) TRE found between common points identified in US and rigid or deformable MRI images. Deformable registration was found significantly better than rigid registration in terms of Dice, Hausdorff and TRE ($p < 0.01$).

Conclusions: In conclusion, deformable registration is significantly more accurate than rigid registration for brachytherapy MRI-US fusion. In average, both Hausdorff distance and TRE for common points are within 2mm. This study demonstrates that the deformable registration is sufficiently accurate and precise for use in focal HDR prostate brachytherapy treatment.



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[American Brachytherapy Society](#)
 12100 Sunset Hills Rd, Suite 130
 Reston, VA 20190
 703-234-4078
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