An assessment of MRI distortion for the purpose of radiotherapy treatment planning

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Purpose/Objective: With growing interest in the use of magnetic resonance imaging (MRI) for radiotherapy treatment planning (RTP), the distortions associated with this modality need to be measured and their clinical impact understood. This work has measured system-related geometric distortion for different MRI scanners and imaging sequences and placed this in context of radiotherapy treatment positions.

Materials and Methods: An MRI phantom designed to meet AAPM standards was imaged on two different MRI scanners. The phantom was a square PMMA phantom filled with water, with outer dimensions of 330.2 x 330.2 x 101.6 mm³ and containing a 2D grid pattern. The first MRI scanner was a Siemens 3 T Verio with a 70 cm bore and the second was a Philips 1.5 T Intera Achieva Nova Dual with a 60 cm bore. A number of acquisition sequences including variations of both spin echo and gradient echo sequences with appropriate T1 and T2 weightings were investigated. On the Siemens scanner, the sequences were performed both with and without the application of a 2D correction algorithm. Assessment of the distortion present in the individual images was determined by comparing the position of grid points in the MRI images to that of CT verified, known positions. The distortion analysis was performed using in house developed software (MATLAB). The significance of the distortion for different radiotherapy treatment sites was evaluated by ascertaining the treatment positions of critical structures relative to the MRI isocentre.

Results: Results demonstrated a considerable variation between different sequences and scanners. Mean differences on the Verio scanner ranged from 0.69±0.49 to 1.32±0.78 mm whilst the maximum difference ranged from 2.39±0.70 to 4.19±0.44 mm with the 2D correction applied. Without the correction algorithm, distortion values were 1.19±0.86 to 1.94±1.49 mm for the mean differences and 3.19±0.70 to 6.57±0.44 mm for the maximum differences. On the Intera Achieva scanner average differences ranged from 0.51±0.46 to 1.12±0.89 mm whilst the maximum ranged from 3.33±0.70 to 8.42±0.29 mm. The maximum distortions were predominately found to increase with the increasing distance from the isocentre. For breast radiotherapy treatments, the maximum position of the breast 257.3±38.5 mm from the isocentre for a 70 cm MRI bore. Whilst maximum distortions exceeded 2 mm for all of the sequences investigated, the phantom didn’t allow for measurements from isocentre to these points relative to breast therapy. The distortion information obtained was limited by the design of the phantom utilised in the study and as a result, work is currently under way in order to design an MRI distortion phantom for RTP investigations.

Conclusions: The degree of MRI distortion varies with the radial distance from the isocentre and therefore its impact on RTP is site specific. This distortion is also dependant on scanner and sequence applications. The clinical impact of these distortion values needs to be assessed, particularly for the higher values.

Hierarchical enhanced non-rigid registration for target volume correction and propagation

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Purpose/Objective: Target volumes change during fractionated radiotherapy (RT). We propose and evaluate an automated approach to project a 3D-segmentation set of the prostate into the subsequent imaging sets at any time point during RT by using intensity-based image registration techniques.

Materials and Methods: Sequential CT sets during RT of patients presenting carcinoma of the prostate were used. Five doctors outlined the prostate in a blinded fashion, defining intra-observer and inter-observer variability. Manual segmentation variability was compared to both automated affine and elastic registration, using a hierarchical enhanced non-rigid registration algorithm (HERA). HERA (Andronach et al. Medical Image Analysis 2008) compensated for spatial changes of the prostate over time (i.e. during RT) by estimating both an affine and an elastic spatial transformation that optimizes an image similarity measure (i.e. cross correlation) extracted directly from the image intensities. This specific registration algorithm uses a hierarchical strategy in which the images to be registered are progressively and adaptively subdivided into smaller finite sub-regions that are locally affine registered. The local variations were used for subsequent adaptations and corrections.

Results: The overall mean inter-observer variability of the affine registration was 2.76 ± 1.4 mm for the affine registration and 2.16 ± 2.26 mm for the elastic registration. These values were comparable to the inter-observer variability of target volume definition by manual segmentation (1.52 ± 1.40 mm). The maximal deviation of 15.4 mm for the inter-observer segmentation was reduced to 10.5 mm by the affine registration and to 8.0 mm by the elastic registration. The propagated contours by elastic registration were inside the confidence interval of the mean of the manually segmented contours in larger regions than with affine registration (p < 0.05).

Conclusions: An elastic registration algorithm as HERA can perform the prostate volume reassessment for repetitive CT during RT for the purpose of position verification, thus target volume adjustment and on-line plane reoptimization allows to minimize PTV margins. The inter- and intra-observer deviations were greater or similar to the variance of the population formed by deviations in contouring for the