MRI-based radiotherapy treatment planning for prostate cancer—Assessment of geometric distortion and detection of fiducial markers

Background
The superior soft tissue contrast of magnetic resonance imaging (MRI) compared to computed tomography (CT) has urged the integration of MRI and exclusion of CT in prostate radiotherapy treatment, referred to as an MRI-only workflow. Such a workflow can eliminate image registration errors between the CT- and MR-images but incorporates multiple challenges. MR-images lack electron density information, needed for absorbed dose calculation. MR-images are therefore converted to synthetic CT (sCT). Geometric distortion may exist in MR-images and could lead to dosimetric errors. Intra-prostatic gold fiducial markers (GFM) appear hyper-intense on CT-images and identification is straightforward. On MR-images the GFM appear as signal voids and identification is difficult. The need for dedicated MRI-sequence, development of quality assurance tools and clinical studies are therefore evident before an MRI-only workflow can be integrated as a clinical routine.

Methods
A phantom based method was developed to assess dosimetric impact from geometric distortion in an MRI-only workflow. An MRI-sequence dedicated for sCT generation was developed. The dosimetric accuracy of a commercially available sCT generation software was validated in a clinical multi-center study. For GFM identification, an MRI-sequence was developed and validated in a human observatory study. An automatic GFM identification software was developed. To indicate a correct GFM identification a CT- and MRI-independent method was developed.

Results
The developed method for assessing dosimetric impact from geometric distortion was determined fit for the purpose. The dosimetric effects of geometric distortion for a dedicated MRI-sequence in an MRI-only workflow was quantified and no clinically relevant effects was found. The clinical multi-center study showed no clinically relevant dose difference between the MRI-only and conventional workflow. The developed MRI-sequence and software for GFM identification had a human and computer identification accuracy of 97 % and 81 %, respectively. The method developed for independent indication of correct GFM identification is well suited and has sufficient accuracy.

Importance
The conducted research has paved the way for an ongoing MRI-only study (25 patients included). This will result in smaller cost for the hospital, less manual labor for the personnel and eventually enable a treatment with less side effects.

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