Impact on proton range estimates of a novel magnetic resonance based metal artifact reduction algorithm

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Main Objectives

- Metal artifacts in computed tomography (CT) can lead to delineation and dosimetric errors in radiotherapy (RT). Such artifacts may be addressed by metal artifact reduction algorithms (MARs).
- To potentially improve the current MARs applied to RT, such as the clinically oMAR algorithm (Philips Healthcare), we recently proposed an MR (magnetic resonance) based MAR, called kerMAR (kernel regression MAR).
- In this work, we evaluate the impact of kerMAR, oMAR and a simple manual water correction technique on the calculated range estimates in simulated proton beams, further comparing to the calculated depth at maximum dose in similar photon beams.

Introduction

Metal implants in (radiotherapy) patients lead to CT artifacts, which in turn can lead to delineation and as well as dosimetric errors. This is of particular concern for the relatively newly introduced proton therapy that can be more sensitive to CT value errors [1]. While these artifacts are addressed by MARs such as the clinically used oMAR algorithm, the MAR efficacy varies over patients with the extent of the corruption; oMAR in particular has been found to provide only negligible dose accuracy improvements for photon beams through the oral cavity[2] and, while improving water equivalent thickness estimates for protons, to leave behind some residual effects [3].

To address this issue, we recently presented a novel MAR that uses tissue information on a co-registered MR image to estimate replacement CT values. This algorithm (kerMAR, kernel regression MAR) combines kernel regression on uncorrupted CT value / MR patch pairs along with a forward model of the CT artifacts to predict uncorrupted CT values [4].

In this work, including a phantom and retrospective patient data, we evaluate the impact of kerMAR and oMAR as well as a simple manual water correction technique on the calculated distal 50% dose point (D50) in simulated proton plans. For comparison, we perform the same evaluation with photons, considering the estimated depth at max dose (Dmax).

Materials

A T2w MR and CT scan of a real shank phantom with and without 6 surgical metal markers were acquired, referring to the CTs as Filtered Back Projections (FBPs). Using the acquired images, we calculated the kerMAR images. We acquired the oMAR images from the scanner and, using the FBP as template, created the manually water corrected images. Four axial phantom slices are shown on fig. 1 left, including the uncorrected reference with metal pins added computationally using threshold-guided manual delineation. From the clinical database we acquired and created the same image sets calculated the kerMAR images. We acquired the oMAR images from the scanner and, using the FBP (Philips Healthcare), we recently proposed an MR (magnetic resonance) based MAR, called kerMAR (kernel regression MAR).

Methods

We devised photon and proton dose plans with one beam perpendicular to the phantom surface and through artifact corrupted regions near the 6 markers on the phantom (beam orientations shown as red arrows on fig. 1 left). We created similar plans on each of the 9 patients, with the beams angled through the oral cavity (fig. 1 right). As shown on fig. 2, we then extracted the central profile depth dose curves for all plans from which we calculated Smax for the photons and D50 for the protons.

Results

Fig. 3 shows the phantom depth/dose differences from the uncorrected reference averaged over the 6 beams. Results are between −0.5 − 3mm. We note that manual overwrite stands out while kerMAR and oMAR, for protons, are statistically more similar as compared to FBP.

Discussion and Conclusions

- In the phantom, the protons and photons were similarly affected by the different MARs, except for water overwrite which affected the photons the most. This was due to beam 3 (fig. 1) and the similar beam 5 (not shown) that were affected surprisingly large Smax decreases with photons. This contrasts with the patients, where the protons were most affected and photons virtually unaffected, again with water overwrite being the most invasive. Our results (this suggest 1) that protons are particularly affected by larger anatomical changes compared to photons, but not necessarily by smaller degrees of corruption, and, accordingly, 2) that water overwrite, which provides major changes in complex regions such as the oral cavity, should be undertaken cautiously when proton planning.
- The automatic algorithms oMAR and the novel kerMAR performed similarly in the relatively homogeneous phantom, and were for protons statistically more similar than either to FBP. However, in the more complex patients, oMAR proved more similar to FBP than to kerMAR, possibly due to the residual streaks left by oMAR that kerMAR seeks to address.
- The observed proton range variations of −0.5 − 3mm, especially from water overwrite but potentially even between kerMAR and FBP/oMAR, are of a similar magnitude to the margins commonly used in proton RT to account for errors such as patient motion and are thus of some practical concern.

References


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