First clinical release of an online, adaptive, aperture based IGRT strategy in IMRT to correct for inter- and intra-fractional rotations of the prostate

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Introduction

In image guided, intensity modulated radiotherapy (IGIMRT) of prostate cancer, inter- and intra-fractional movements of the organ are the main reason for safety margins, i.e. the distance between the clinical target volume (CTV) and the planning target volume (PTV). Implanted gold markers allow pre- and intra-treatment assessment of prostate movements in kV and MV projections. In addition to translations, significant rotations of the prostate (15° or more) have to be expected. While couch shifts can be applied for vector corrections, it is simply impractical to rotate patients at that magnitude. Therefore, we make use of the multi leaf collimator to adapt beam apertures instead.

Methods

We present the first clinical release of an online, adaptive, aperture based IGRT protocol for IMRT of the prostate that works without re-positioning of the patient on a standard linear accelerator equipped with an integrated multi leaf collimator (MLC 80 leaves 1 cm), 4 cylindrical gold markers are auto-detected in planar projection images captured on-the-fly, no initial cone beam acquisition is required (Fig. 2). Translations, rotations, and organ swelling/shrinkage are immediately reconstructed. MLC leave positions for all IMRT segments are adapted to the transformed PTV and organs at risk (OARs) within seconds. For that purpose, a new record and verify system: open-radART was developed to integrate real-time 3D treatment planning features and to control conventional linear accelerators (Elekta Synergy / RTD 7). Direct interfaces to the panels (kV and MV imaging) were embedded in the application to enable fast image feedback loops.

Results

Since 2009 we have treated >100 patients in this adaptive protocol (ongoing), 1013 fractions (9117 kV and MV images) of first 39 patients were analyzed and are presented here. In 7/1013 fractions, movements exceeded pre-defined limits (>30°/±20 cm). 833/1013 fractions showed marker migrations ≤2 mm; rigid transformations were analyzed from these fractions: Absolute daily L-R rotations were found to be 5.3±4.9° (max. 30.7°) (numbers represent mean of means ± standard deviation of means per patient – the mean value over the whole population was 0°). 3D vector transformations (Δx,Δy,Δz) of gold markers relative to skin tatoes were 9.3±4.4 mm (max. 23.6 mm). Intra-fractional movements in 7.7±1.5 minutes (max. 15.1 min) between first pre-treatment radiographic and last beam’s EPI showed further L-R rotations of 2.5±2.3° (max. 26.9°) and 3D vector transformations of 3.0±1.7 mm (max. 10.2 mm) (Fig. 3). From analysis of 5831 MV portal images we conclude, that addressing intra-fractional errors by just-in-time adaptation of leaf positions for a following beam, based on recent kV and MV images captured on-the-fly, could further reduce margins down to 3 mm for the prostate (95% probability of 95% isodose coverage of the CTV); seminal vesicles to be discussed separately because of their non-rigid movements / shape changes.

Conclusion

Having successfully integrated real-time imaging, real-time treatment plan adaptation and treatment delivery in one clinically released application, we are happy to announce that interested researchers and clinical investigators can download our software from fips://192.168.141.15/radART/openSource for free (please contact the authors for access, www.open-radART.org). Further developments and contributions from other research institutions welcome! (The in-house development of the software open-radART is CE-certified, conform with the regulations of the European standard EN/ISO 13485:2003 + AC 2007, CE 0408. As a record and verify system, it is classified as a medical device class IIb and can be used clinically elsewhere.)

Acknowledgement / Disclaimer
This work was supported in parts by Elekta.

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