Evaluation of Three IGRT Approaches for Prostate Cancer Treatment

Introduction: Different IGRT and adaptive approaches have been proposed lately for prostate cancer treatment. However, there is no clear comparison and clinical evaluation of these approaches. In this study, we performed a retrospective study to evaluate 3 IGRT approaches, and compared them with respect to the dosimetric achievement and treatment efficiency.

Method & Material: Two online IGRT and one hybrid adaptive treatment were simulated and evaluated retrospectively using daily CBCT images obtained from 5 prostate cancer patients treated with total dose 64 Gy delivered in 20 fractions (3.2Gy x 20). For each daily treatment, two CBCTs obtained at the pre- and post-treatment delivery were used in the study. Online IGRT approaches include (1) Online-correction: a pre-treatment IMRT plan with 3mm CTV-to-PTV margin was delivered following online target position correction (couch shift alone) based on pre-treatment CBCT image; and (2) Online-planning: an online IMRT plan on the pre-treatment CBCT image with 3mm target margin was accomplished and delivered. The hybrid adaptation approach consists of the online prostate position correction and delivery of a pre-treatment IMRT plan with no target margin for the first week of the treatment, and an offline adaptive inverse planning modification with using the first week of post-treatment CBCT images for the remaining treatment. Treatment dose for all 3 approaches were constructed using the daily post-treatment CBCT images and deformable image registration. Evaluations were all based on the treatment dose distribution in organs of interest for all patients.

Results: Figure 1 shows the DVHs of the target (CTV), the rectum and bladder for the patient 1. Figure 2 shows the dose-volume parameters of target, rectum and bladder calculated using the treatment dose in each organ of interest for all 5 patients. These parameters have been used in the clinical planning for the hypo-fractionation (3.2Gy x 20) of prostate cancer radiotherapy, which include the minimal target dose (D99: the minimal dose in the 99% of CTV volume); the bladder volume with dose >= 59.4 and 64.1 Gy; and the rectal volume with dose >=56.5, 59.4 and 64.6 Gy.

Figure 1
Discussion: Online-correction technique, IMRT treatment with 3 mm CTV-to-PTV margin and the online CBCT guided target position correction (translational shift only), cannot fully compensate for the intra-treatment prostate and seminal vesicle motion. One of 5 patients (Patient 1) had treatment dose reduction of 20% in the target. In addition, the online-correction also had larger normal organ dose for most of the patients comparing to the other two techniques. The hybrid-adaptation and online-planning were quite comparable with respect to both target dose coverage and normal organ dose-volume limitation. One patient (Patient 4) showed a relatively larger rectal dose for the hybrid-adaptation technique than the one for the online-replanning, due to an extremely large rectum volume on the planning CT which has been included, with the first week CBCTs, in the adaptive inverse planning.

With respect to treatment efficiency, Online-correction implemented on the onboard CBCT Linacs is the simplest one, and can be broadly implemented in the routine clinic, but 3 mm pre-designed target margin cannot properly compensate for the intra-treatment target motion. Adding one extra offline adaptive inverse planning after the first week of the treatment, Hybrid-adaptation technique can be implemented in clinic, but requiring a proper software tool and change of clinical work flow. Daily online inverse planning required for Online-planning approach is an unrealistic approach at the current time, and also shows limited improvement for a small group of patients comparing to the hybrid-adaptation. It could be an option to implement Hybrid-adaptation, while identify which patient may need to have extra adaptive planning modification.