Introduction

Image guided radiation therapy (IGRT) is an established radiation treatment for localized prostate cancers. Our group have been treating prostate cancer patients using an in room CT-on-rail since 2000. IGRT, although corrects for the inter-fractional variationalizations of the target (prostate and seminal vesicles), it does not correct for the daily changes in shape of the target, nor the changes in shape and sizes of the adjacent normal tissues (bladder and rectum). These variations may lead to under-dosing of the target and over-dosing of the normal tissues, thus, undermining the effectiveness of IMRT despite IGRT corrections.

With the advent of modern imaging modalities such as KV cone beam, MV cone beam or in room CT-on-rails, the changes in location, shape and volumes of the target and normal critical structures can be assessed immediate prior to each radiation treatment deliveries. In theory, adaptive radiotherapy (ART) is such an approach to correct for these variations. Issues that need to be resolved for adaptive radiation therapy include the time and frequency of adaptation, feasibility of the technique, manpower involvement, and clinical relevance of the technique.

Li and colleagues (1,2) proposed a two-step process of online replanning which includes segment aperture morphing (SAM) and segment weight optimization (SWO). Segment aperture morphing corrects for both deformation and translation of the target by means of multileaf collimator (MLC) adjustments, and segment weight optimization improves on the SAM plan by determining the optimum monitor units for each segment. This strategy when retrospectively tested on several prostate cases, was found to be effective and required only about 8 minutes. They proposed the avoidance of IMRT quality assurance for each adaptive plan because it is just a minor modification of the segment apertures and weights (no new leaf sequencing). Using such methods, they have treated 8 patients in selected fractions.

Purpose/Objective

Image guided radiation therapy (IGRT) of prostate cancers have been well accepted. However, IGRT mainly corrects for the interfractional prostate movements; the anatomic changes of the prostate gland and adjacent critical structures and the interfractional movements of adjacent organs are not taken into account. Using similar technique as Li (with modification in contouring, specific planning strategies and multiple QA checks), we have now clinically deployed “real-time treatment planning” (RTP) daily for the first 10 fractions (and more as needed) for every primary prostate cancer patient presented for treatment at our clinic in addition to IGRT. The technique, rationale and experience of the first 60 RTP treatments are presented here together with another abstract from our group (Merrick). To our knowledge, this is the first clinical implementation of daily treatment replanning (real time adaptive targeting) for a series of patients.

Materials and Methods

In the department of Radiation Oncology at Morristown Medical Center, Morristown, New Jersey, a CT-on-rails (Fig. 1) at the radiation treatment suite generates high-quality diagnostic CT images which can be used used for on-line real time treatment planning (RTP).

The RTP process is as follows: a) daily CT images are acquired with an in-room diagnostic CT-on-Rails for IGRT in conjunction with RTP; b) treatment plan is loaded, new target is contoured, new tissue contours (prostate, rectum and bladder) are drawn by physician, c) the new contours are compared to the initial contours to ascertain minimal deviations; d) a new IMRT (figure 2) is optimized against the TC and structures of the current daily CT (RTP); e) the original plan (based on the previous CT simulation) plan after IGRT shift is compared to the RTP plan: f) if RTP plan is better as indicated by dose volume histogram (DVH) and isodose curves, it will be delivered after g) necessary QA process by comparing point dose and fluence map using a second TPS, and verifying the monitor units to be delivered. This entire process takes less than 20 minutes (not including IMRT delivery). 60 RTP has been delivered (10 daily RTP) per patients in 6 consecutive patients.

Our treatment technique differs from that as proposed by Li in that a new, re-optimized IMRT plan is employed. In our process, the new re-optimized plan is copied to both Prowess and Pinnacle for QA fluence map calculation at the same depth of the same flat surface phantom. The fluence and point dose generated are then compared using IMRT matrix® software with standard gamma analysis. The final plan is deemed acceptable if the gamma passing rate is better than 95%. The corresponding QA plan is subsequently measured with QA device in the same day after patient treatment. Both point dose and fluence map are then compared against that previous calculated by Prowess treatment planning software (primary TPS for online adaptive radiotherapy).

Results

Auto-contouring via autosegmentation was inadequate (always required physician modifications) and time saving was no achieved when compared to manual re-contourings. The RTP plan is always superior to or equal to the original IGRT plan superimposed onto the re-contoured structures. In 20% of the cases, the CTV-DVH by RTP improved by >10%. With regard to the recontoured CTV (prostate), a slight change in manual contouring variation can lead to significant change in % volume variation or absolute volume variations. Representative isodose curves and DVH (dose-volume-histogram) comparisons of IGRT as opposed to RTP are shown in Figures 3 and 4 respectively.

Conclusion

Daily RTP is feasible for prostate cancer treatments and is superior to IGRT. RTP is especially necessary with extreme anatomic changes. RTP holds important role for hypofractionation delivery. Even with our diagnostic quality CT images, current autosegmentation contouring program is inadequate. Improvements in autosegmentation contouring may allow more widespread daily RTP implementations.

We also studied the effect of contour variations when the target or normal tissues are drawn manually by various physicians. The effect of contour variations may have significant effects in the volume of the target or the normal tissues structures. For example, with an initial prostate size/volume of 15, 20, 30, 40 and 50 cc, a 1 mm increase in contour variation (all 6 directions) results in an increase volume of 26%, 24%, 21%,19% and 17% respectively, with corresponding increases in absolute volumes of 3.6cc, 4.8cc, 6.2cc, 7.4cc and 8.6cc respectively. The anatomies of rectum and bladder can vary significantly. Rectal dose improved significantly with RTP when compared to IGRT. In one extreme case, the rectal dose improvement is as shown in table 1.

Table 1: Rectal dose of RTP vs. IGRT plans based on a prescription dose of 7746Gy. V40 = % rectal volume receiving 4000cGy, V50 for 5000cGy and so on.

<table>
<thead>
<tr>
<th>PLAN</th>
<th>V40 (%)</th>
<th>V50 (%)</th>
<th>V60 (%)</th>
<th>V70 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTP</td>
<td>47.1</td>
<td>29.9</td>
<td>18.6</td>
<td>7.8</td>
</tr>
<tr>
<td>IGRT</td>
<td>63.8</td>
<td>49.3</td>
<td>38.0</td>
<td>26.5</td>
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Reference