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A study on planning organ at risk volume for the rectum using cone beam computed tomography in the treatment of prostate cancer

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ABSTRACT

In this study, we analyzed planning organ at risk volume (PRV) for the rectum using a series of cone beam computed tomographies (CBCTs) acquired during the treatment of prostate cancer and evaluated the dosimetric effect of different PRV definitions. Overall, 21 patients with prostate cancer were treated radically with 78 Gy in 39 fractions had in total 418 CBCTs, each acquired at the end of the first 5 fractions and then every alternate fraction. The PRV was generated from the Boolean sum volume of the rectum obtained from first 5 fractions (PRV-CBCT-5) and from all CBCTs (PRV-CBCT-All). The PRV margin was compared at the superior, middle, and inferior slices of the contoured rectum to compare PRV-CBCT-5 and PRV-CBCT-All. We also compared the dose received by the planned rectum (Rectum-computed tomography [CT]), PRV-CBCT-5, PRV-CBCT-All, and average rectum (CBCT-AV-dose-volume histogram [DVH]) at critical dose levels. The average measured rectal volume for all 21 patients for Rectum-CT, PRV-CBCT-5, and PRV-CBCT-All was 44.3 ± 15.0, 92.8 ± 40.40, and 121.5 ± 36.7 cm^3, respectively. For PRV-CBCT-All, the mean ± standard deviation displacement in the anterior, posterior, right, and left lateral directions in centimeters was 2.1 ± 1.1, 0.9 ± 0.5, 0.9 ± 0.8, and 1.1 ± 0.7 for the superior rectum; 0.8 ± 0.5, 1.1 ± 0.5, 1.0 ± 0.5, and 1.0 ± 0.5 for the middle rectum; and 0.3 ± 0.3; 0.9 ± 0.5; 0.4 ± 0.2, and 0.5 ± 0.3 for the inferior rectum, respectively. The first 5 CBCTs did not predict the PRV for individual patients. Our study shows that the PRV margin is different for superior, middle, and the inferior parts of the rectum, it is wider superiorly and narrower inferiorly. A uniform PRV margin does not represent the actual rectal variations during treatment for all treatment fractions. The large variation in interpatient rectal size implies a potential role for adaptive radiotherapy for prostate cancer.

Introduction

Radiotherapy plays an important role in improving the survival rate of patients with prostate cancer. Pollack *et al.*[1] have shown that an increase in the prescribed dose from 70 Gy to 78 Gy results in a significant improvement in freedom from biochemical failure for patients with intermediate to high-risk prostate cancer. Several studies have also shown that dose escalation not only improves the local control but also prevents prostate-specific deaths.[2-6] However, the most important limiting factors in dose escalation of prostate cancer radiotherapy are bladder and in particular rectal toxicities. Intensity-modulated radiation therapy has been shown to reduce normal tissue toxicity when compared with conventional 3-dimensional conformal radiation therapy.[3,4] The rectal dose-volume histogram (DVH) plays a vital role in identifying patients with low and high risks of developing late bleeding.[7] However, the rectum on the planning computed tomography (CT) is often in a different position or size during treatment. Figure 1 illustrates an example of a large change in the rectal volume from the planning CT (on the left side of Fig. 1) compared with the cone beam computed tomography (CBCT) acquired on the fourth fraction (on the right side of Fig. 1).

The planning organ at risk volume (PRV) is a volume created by adding a margin to organs at risk that encompasses organ motion and setup error during treatment.[8] The International Commission on Radiological Units and Measurements (ICRU) recommends that

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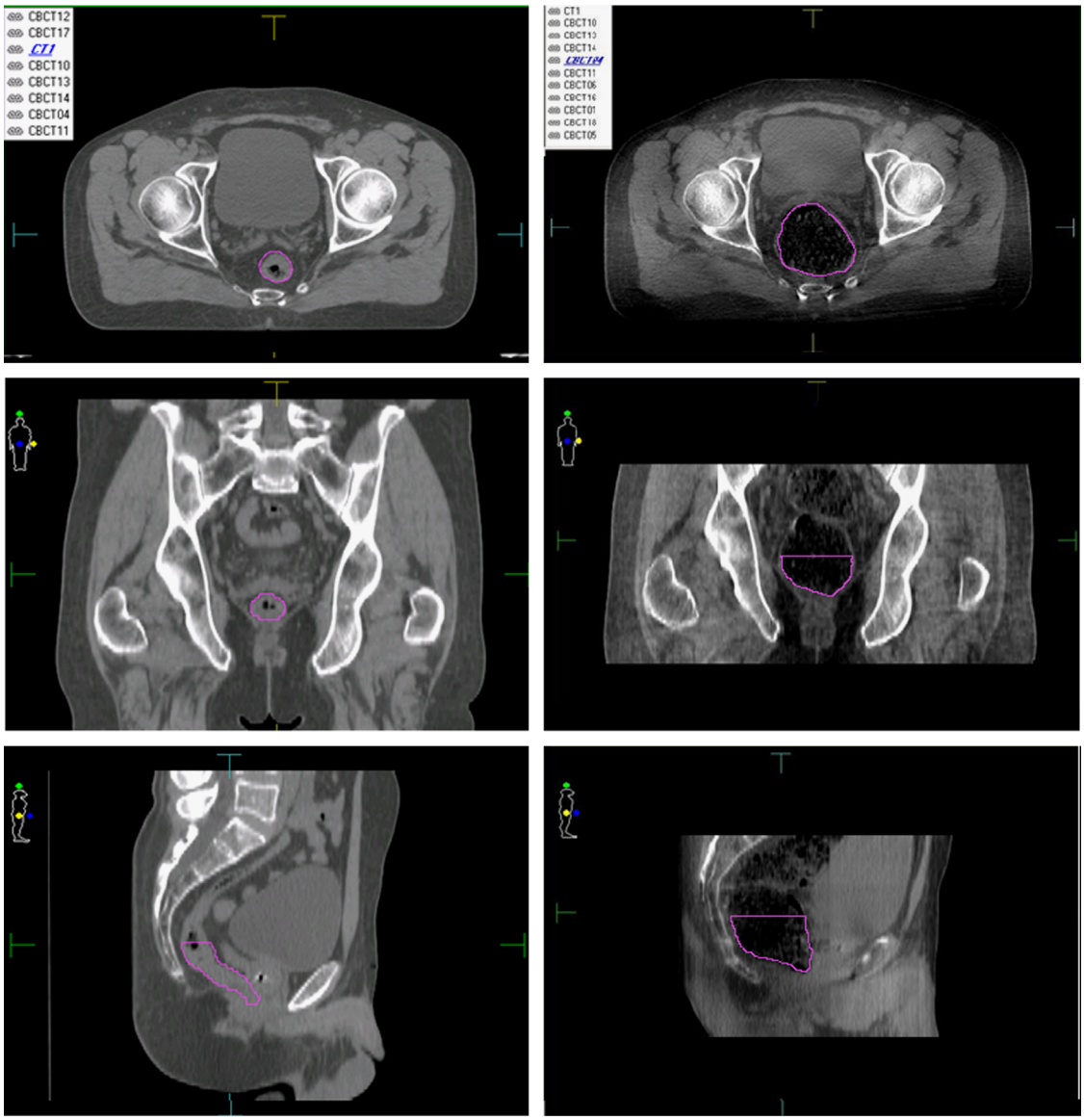

Fig. 1. Rectum volume variation between planned CT and CBCT acquired on fourth fraction. (Color version of figure is available online.)

the dose received by the PRV is reported routinely. The recent ICRU report 83 discusses in detail about the use of PRV margin but no clear margin has been recommended in this report.[9] With the emergence of image-guided radiotherapy (IGRT), detailed information is now available on pretreatment positioning of the target, which was not available before the IGRT era. In the clinical environment, the concept of PRV is not commonly used for all critical structures during treatment planning due to lack of data on the margin around organs at risk (OARs). For treatment sites where the critical structures are more likely to move during treatment, the PRV may help in planning radiotherapy for OAR avoidance to achieve a balance between planning target volume (PTV) coverage and PRV avoidance. In situations where 2 plans are available for comparison and PTV coverage is the same, the dose to the PRV can be used to select the best plan. In prostate cancer, it has been demonstrated that the PRV correlates better with rectal toxicity than the rectal volume on the planning CT alone.[10] Thor *et al.*[11] have shown that a PRV with narrow margins correlates with late rectal toxicity. Similarly, Dias *et al.*[12] have also shown that PRV dose correlates with acute gastrointestinal complications and recommended that it may be used as a tool to predict and control the occurrence. Most of the studies discussed assume a uniform margin around the rectum along the craniocaudal direction or the transverse direction or along both.

To date, the PRV margins have been derived theoretically or based on margins obtained from patient groups other than patients with prostate cancer, or from repeat CTs that may not accurately replicate the treatment conditions. Hence, in this study, an effort has been made to determine the PRV margins for the rectum based on a series of post-treatment CBCTs that represent the actual treatment position and organ locations during treatment. Our primary aim was to determine if the PRV margin derived from the first 5 fractions is sufficient to represent the rectum PRV margin for the remaining fractions. Our secondary aim was to compare the average dose received by the rectum during radiotherapy during treatment, based on the CBCTs, with the dose received by the rectum on the planning CT.

Methods and Materials

A total of 21 patients treated at our center undergoing radical radiotherapy for prostate cancer were selected for this study. A dose of 78 Gy in 39 fractions was prescribed to all the patients with 95% of prescription dose covering 99% of the target volume. All treatment fractions were aligned to the isocenter with pretreatment IGRT of kV/kV orthogonal imaging matched to gold seed fiducials implanted in the prostate with