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Plan of the day selection for online image-guided adaptive post-prostatectomy radiotherapy

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ABSTRACT

Purpose: To compare the cone-beam CT (CBCT) soft tissue localization disparity between radiation oncologists (RO) and radiation therapy technologists (RTT) in a novel online protocol of image-guided adaptive radiotherapy to the postoperative prostate bed.
Method: Using the planning CT and pre-treatment CBCTs from the first week of radiotherapy, four adaptive plans of different sizes were derived for each of eight post-prostatectomy patients. Four ROs collectively defined the reference answer, i.e. the plan of the day and isocentre correction for 40 CBCTs taken in weeks 2–6 of treatment for each patient. RTTs were randomly assigned five of these CBCTs; and asked to record their plan of the day selection and isocentre correction. RTT selection and reference answers were compared. The distance between the RTT selection and the reference answer was calculated.
Results: A total of 33 RTTs took part in this study. The average difference in CTV volume (reference answer-RTT selection) was 1.32 cm^3 (SD 29 cm^3) overall. The average difference between reference answer and RTT isocentre coordinates was SI 1 mm (SD 4.8 mm), LR 1.1 mm (SD 4.0 mm) and AP −0.2 mm (SD 3.9 mm). Distance of superior 8 mm, inferior 6 mm, left 4 mm, right 2 mm, anterior 6 mm and posterior 6 mm covered 100% of the CTV in 90% of fractions.
Conclusion: The difference between RTT and RO selection of adaptive volumes is small and can be accounted for in a clinically acceptable CTV to PTV margin. Adaptive post-prostatectomy radiotherapy is feasible, in the setting of an academic center although at the moment, we have insufficient evidence to suggest that margins can yet be reduced with IGART with the current protocol.
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Randomized trials in the post-prostatectomy setting suggest that local failure is the predominant treatment failure pattern and adjuvant radiotherapy reduces this by approximately two-thirds [1,2]. However these studies used a non-conformal technique with low chance of geographical miss but higher toxicity. Since then, consensus guidelines have been developed on the clinical target volume (CTV) definition for conformal post-prostatectomy radiotherapy [3–5]. A recent analysis of the dose response in the post-prostatectomy radiotherapy setting suggests a 3% reduction in biochemical failure per Gray with dose escalation [6]. Similar results have been found in the intact prostate setting, but dose escalation was associated with more side effects [7]. Post-prostatectomy dose escalation up to 75.6 Gy has been reported with image guided radiotherapy (IGRT) [8]. However, even with IGRT, post-prostatectomy radiotherapy has a higher incidence of gastrointestinal and genitourinary toxicity with a dose-modifying factor of 1.2 compared to intact prostate radiotherapy [9].

The prostate bed deforms considerably between each fraction of radiotherapy [10–12]. Fiorino et al. observed that the rectum tended to migrate anteriorly into the treated volume during the course of radiotherapy, with a mean shift of 2.5 mm (range −3 mm to 12 mm) [10]. The posterior rectal wall also shifted anteriorly by an average of 6.5 mm. The ratio between largest and smallest bladder volume during radiotherapy varied by a factor of 3.8 (range 1.9–8.8). Fig. 1a and b illustrates one example of variation in size of the prostate bed between the planning CT and a pre-treatment cone-beam CT (CBCT) in the same patient, due to the change in the size of the patient's rectum. It is apparent from this example that rectal distension and prostate bed deformation during radiotherapy may result in both geographical miss of the tumor bed, and greater toxicity through increased dose deposition in the rectum. The era of IGRT and quicker planning software has opened a window of opportunity for adaptive radiotherapy in the post-prostatectomy setting [13]. Whilst IGRT corrects for changes in the position of the prostate bed, online image-guided adaptive

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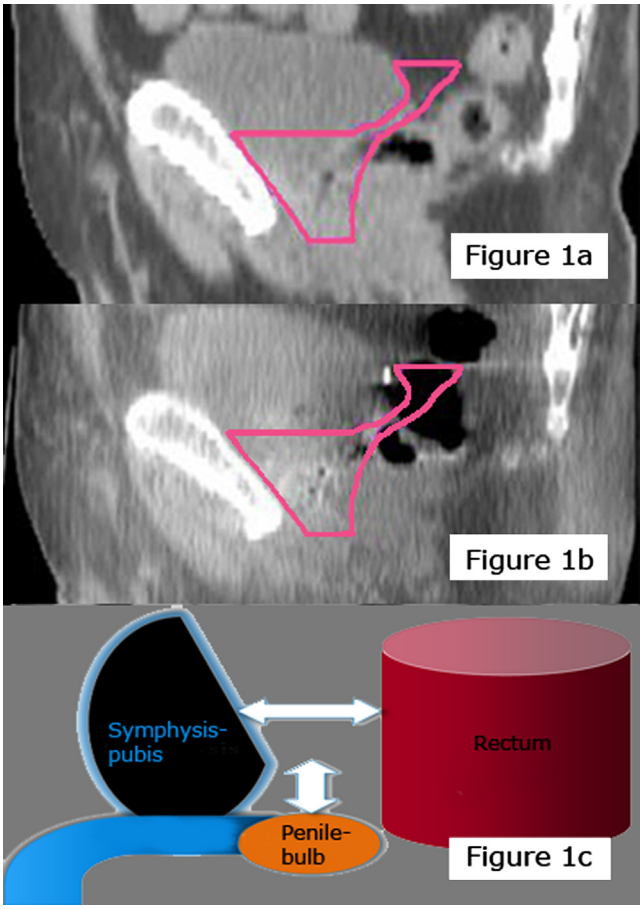

Fig. 1. (a) and (b): Planning CT and pretreatment CBCT from the same patient, illustrating the problem of deformation of the prostate bed caused by gaseous filling of the rectum between the planning CT, and pretreatment CBCT. The pink contour is the CTV. (c) Illustration of a prostate bed sagittal view showing the use of the rectum-pubic symphysis distance to determine the plan of the day selection and SI position based on the penile bulb.

radiotherapy (IGART) can adapt to deformation of size and shape of the prostate bed. As such, IGART may provide a better solution for toxicity reduction whilst maintaining better target coverage compared to IGRT alone.

In 2006, Pos et al. proposed an adaptive technique for bladder cancer where the CTV was contoured on five CT scans taken in the first week of treatment, and the adaptive CTV was created by combining the volume of all CTVs from the first week CT scans. Subsequent CT scans during treatment revealed that this method accounted for the gross deformations of the target seen in bladder cancer radiotherapy [14]. In this study, the adaptive PTV was found to be 40% less than the conventional PTV. In the same year, Burridge et al. reported a "plan of the day" online strategy for adaptive radiotherapy for bladder cancer [15]. Here the treating radiation therapy technologist (RTT) chooses one of several adaptive plans that best fits the target of the day based on soft tissue image registration on pretreatment CT. Our center presently uses a "plan of the day" online IGART strategy to treat bladder cancer in a Trans-Tasman Oncology Group study (Bladder Online Adaptive Radiotherapy (BOLART) TROG 10.01 Study) which has been described previously [16,17]. This protocol uses the pretreatment CBCTs from the first week of radiotherapy and the planning CT to create several plans of different sizes which are used weeks 2–6 of treatment. The present study was conducted as a preclinical study to estimate the accuracy of RTT selection of the "plan of the day" adaptive radiotherapy strategy in the post-prostatectomy setting.

Method

This study followed a prospective ethics board approved protocol; all RTTs who took part gave informed consent. Fig. 2 outlines the schema of the study.

Test material

Patients in this study had completed treatment with standard radiotherapy (not adaptive), and their planning CT and CBCTs were analyzed retrospectively. Patients were treated to a dose of 64–70 Gy in 2 Gy fractions, once daily over six and a half weeks on Varian (Palo Alto, CA) linear accelerators. All patients were instructed to empty their bladder and rectum and drink 750 ml of water an hour before each fraction. Treatment was conducted in the supine position with knee stocks and a footrest for immobilization (Combifix-Sinmed, Civco, Kalona, IA).

Adaptive plan creation

In an online IGART program, the patient would have a pre-treatment CBCT prior to every fraction of radiotherapy. In this study, for each patient, four new adaptive CTVs of difference sizes are created from the planning CT and CBCTs taken in the first week of radio-

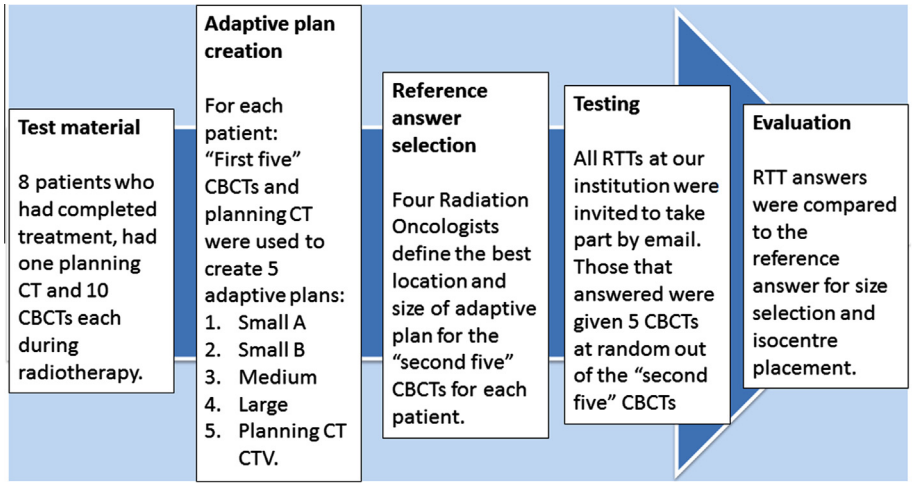

Fig. 2. Flowchart illustrating the schema of the study.