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Prostate brachytherapy

Set-up errors due to endorectal balloon positioning in intensity modulated radiation therapy for prostate cancer

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Abstract

***Purpose*: To investigate the set-up errors and deformation associated with daily placement of endorectal balloons in prostate radiotherapy.**

***Materials and methods*: Endorectal balloons were placed daily in 20 prostate cancer patients undergoing radiotherapy. Electronic portal images (EPIs) were collected weekly from anterior–posterior (AP) and lateral views. The EPIs were compared with digitally reconstructed radiographs from computed tomography scans obtained during pretreatment period to estimate displacements. The interfraction deformation of balloon was estimated with variations in diameter in three orthogonal directions throughout the treatment course.**

***Results*: A total of 154 EPIs were evaluated. The mean displacements of balloon relative to bony landmark were 1.8 mm in superior–inferior (SI), 1.3 mm in AP, and 0.1 mm in left–right (LR) directions. The systematic errors in SI, AP, and LR directions were 3.3 mm, 4.9 mm, and 4.0 mm, respectively. The random (interfraction) displacements, relative to either bony landmarks or treatment isocenter, were larger in SI direction (4.5 mm and 4.5 mm), than in AP (3.9 mm and 4.4 mm) and LR directions (3.0 mm and 3.0 mm). The random errors of treatment isocenter to bony landmark were 2.3 mm, 3.2 mm, and 2.6 mm in SI, AP, and LR directions, respectively. Over the treatment course, balloon deformations of 2.8 mm, 2.5 mm, and 2.6 mm occurred in SI, AP, and LR directions, respectively. The coefficient of variance of deformation was 7.9%, 4.9%, and 4.9% in these directions.**

***Conclusions*: Larger interfractional displacement and the most prominent interfractional deformation of endorectal balloon were both in SI direction.**

Keywords: Prostate cancer; Intensity modulated radiation therapy; Endorectal balloon; Setup error; Deformation

The role of definitive radiotherapy for localized prostate cancer is well established. Many studies of radiation dose escalation for better local control of prostate cancer have been published in recent decades [5,10,22,23]. The results from retrospective analysis or prospective randomized trials all showed that dose escalation improved biochemical control in patients with localized prostate cancer. Notably, in a phase III randomized trial, dose escalation was associated with higher incidence of late rectal toxicity [10]. At 6 years, grade 2 or higher rectal toxicity rates were 26% in the dose-escalation group (78 Gy) compared with 12% in the conventional-dose group (70 Gy).

Several methods to reduce late rectal toxicity have been investigated in prostate radiotherapy. The intensity modulated radiation therapy (IMRT) technique significantly reduced the incidence of late grade 2 rectal toxicity compared with three-dimensional conformal radiotherapy [22]. Another strategy is to reduce the rectal volume within the high-dose region, given that incidence of rectal complications correlates with radiation dose and irradiated volume of tissue [12,13]. Endorectal balloons, designed for the purpose of rectal sparing, have been used in prostate radiotherapy at some institutes. They significantly reduce the rectal volume receiving high-dose prostate irradiation [9]. Besides, prostate immobilization is improved because the endorectal balloon pushes the prostate toward the pubic symphysis. Other studies have demonstrated that endorectal balloons reduce both the prostate movement and variation in rectum filling during treatment [3,21].

However, another investigation found endorectal balloons had the opposite effect on prostate immobilization [20] and failed to reduce interfraction variation. This

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contradictory finding might be explained by the presence of stool or gas in the rectum adjacent to balloon. Extrinsic factors (such as stool, gas, and tension in the pelvic cavity) would cause inconsistent balloon positioning and deformation of the balloon. Moreover, positioning error associated with daily balloon placement may be another issue of concern. To date, the consistency of endorectal balloon placement has seldom been addressed. We conducted this study to investigate the set-up error due to endorectal balloon positioning, and compare systematic (present during all treatment fractions) and random (interfraction) variation. We also evaluated the deformation of the endorectal balloon during daily placement throughout the course of intensity modulated radiation therapy (IMRT).

Materials and methods

Treatment and patient setup

Twenty patients with prostate cancer undergoing IMRT at National Taiwan University Hospital were enrolled in this study. Patient characteristics are shown in Table 1. All patients were treated with 10-MV photon beam from a Siemens Primus Linear Accelerator. Five gantry angles with a total of 35—50 segments were used for the IMRT. The margins for planning target volume (PTV) were 0.6 cm in posterior (toward rectum) direction, and 1.0 cm in the other directions. A total dose of 78 Gy in 39 daily fractions, five fractions per week, was given to the PTV. The 100% prescription isodose curve encompassed al least 95% of PTV in all cases. Less than 5% of PTV received more than 110% of prescription dose. The constraints for bladder and rectum were less than 25% and 17% volume receiving doses of more than 65 Gy, respectively. The isodose curves of one representative patient's plan in transverse and sagittal images are shown in Fig. 1. During the simulation and whole course of IMRT, the patients were immobilized in the prone position with a vacuum bag. Our in-house protocol did not include the insertion of gold markers into the prostate.

Table 1
Patient characteristics

Characteristics	Number	%
Age at diagnosis		
Mean	73.8	
<75	9	45
≧75	11	55
T stage		
T1	3	15
T2	5	25
T3	11	55
T4	1	5
N stage		
N0	20	100
N1	0	0
Pre-treatment PSA (ng/ml)		
<10	7	35
10—20	7	35
>20	6	30
Gleason score		
<7	6	30
=7	7	35
>7	7	35
Treatment target		
Prostate alone	6	30
Prostate + bilateral seminal vesicles	14	70

Placement of endorectal balloon

Daily placement of the endorectal balloon was performed under uniform guidelines for prostate immobilization and rectal sparing. One endorectal balloon was used per patient throughout the entire treatment course with the use of a disposable condom in each fraction. The deflated endorectal balloon was inserted into the rectum, inflated with 60 ml of air [9], and gently pulled toward the anal sphincter. In simulation, a marking sign was made on the endorectal balloon shaft at the level of anal verge. To ensure the reproducible positioning of endorectal balloon, the placement of balloon needs the correction of fitting the marking sign position at anal verge in daily procedure. The marking sign on the balloon shaft was made to ensure the relatively constant position of the balloon in daily placement, but not for the correction of treatment position. In daily pre-treatment set-up, positioning was based on the skin marker of the patient. All patients tolerated the procedure well throughout the treatment course.

Image collection

Electronic portal images (EPIs) were collected weekly from anterior—posterior (AP) and lateral views for each patient. The EPIs were compared with digitally reconstructed radiographs (DRR) of computed tomography scans from pretreatment simulations to evaluate the set-up errors in distance between the endorectal balloon, bony landmarks, and treatment isocenter. The reference point of the endorectal balloon was the center of the air sac in the catheter before inflation. In the lateral view, the reference points of bony landmarks were the apex of the pubic symphysis and the anterior sacral edge at the level of the tip of the femoral head. In the AP view, the reference point was the midpoint between the tips of the bilateral femoral heads. The set-up errors in endorectal balloon positioning were measured from the balloon center to the bony landmarks and treatment isocenter. Displacement of the treatment isocenter relative to the bony landmarks was also measured to evaluate the interfraction positioning variation during the course of IMRT. All measurements were collected in three orthogonal directions [superior—inferior (SI), anterior—posterior (AP), and left—right (LR)] separately. To evaluate the deformation of the endorectal balloon in daily placement, the diameters of the endorectal balloon in the SI, AP, and LR directions were measured from the EPIs for each patient.

Data analysis

The systematic and random errors in the displacement of the endorectal balloon relative to the bony landmarks and