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Research Article

Pre-treatment 2D Scout Verification Tolerances and Dosimetry Effects on OAR for the Cylinder High Dose Rate Brachytherapy Treatment of Vaginal Cuff Cancer

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Keywords

- HDR
- Cylinder
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Abstract

Purposes: to statistically find out the achievable and practical pre-treatment verification tolerances for HDR (high dose rate) cylinder treatment using scout AP (anterior and posterior) /LAT (lateral) images and the corresponding organs at risk dosimetry effects.

Materials and Methods: Five previously treated vaginal cuff cancer patients were randomly selected. All of the patients had prescription of 5 mm above the cylinder surface with 500 cGy per fraction for 5 fractions. The treatment plans were developed using the Oncentra treatment planning system with graphical local optimization method. Two scouts (AP/LAT) were taken during CT (computed tomography) scan day and on the treatment day of each fraction. The dummy source was placed in the cylinder and the tip of the dummy source to the top of the pubic bone vertical distance on the AP scout was recorded. The cylinder diameter was also measured. The LAT dummy source angle relative to the horizontal line was also recorded. The treatment for each fraction was then reconstructed using AP/LAT scout images. The source position was registered back to the planning CT. A dummy cumulative plan was then created with a prescription of 2500 cGy for 1 fraction.

Results: The AP shifts were ranging from -5 mm to 10 mm and the LAT shifts were ranging from -13° to 9°. The percentage median dose difference can be ranging up 0.3%-14% for the rectum and -17.8%-8.0% for the bladder. Based on the statistics results, we propose the pre-treatment simulation tolerances: trying to maintain the cylinder in AP direction shift under 5 mm, a warning zone is 5 mm-10 mm. For the lateral angle, the tolerance is trying to maintain the angle difference under 5 degree with 5-10 degree as warning zone.

Conclusion: We have done pre-treatment simulation quality assurance study using AP/LAT scout images. The tolerance for this pre-treatment simulation was proposed. The relative dosimetry effects for the rectum and bladder were reported.

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INTRODUCTION

The cylinder High Dose Rate (HDR) brachytherapy alone has been considered an effective way to treat early stage vaginal cuff cancer [1]. Although the Organs At Risk (OAR) dose is much lower than the tolerance for complication, [2] however, it is also important to do certain quality assurance to make sure the correct applicator is used and the treatment position is reproducible based on the American Association of Physicists in Medicine (AAPM) task group report 56 and 59 [3,4]. A recent report [5] has found out that the most often happened errors during HDR treatment are the wrong application treatment length and applicator size. "Additionally, not enough patients are being imaged prior to the administration of their brachytherapy" [5]. In current brachytherapy era, it is easy and available to do certain pre-treatment simulation for HDR treatment to prevent such errors happen. However, extensive re-planning CT imaging may not be necessary per recent study [6]. Previous studies have been done about the planning optimization, [7-9] treatment time verification, [10,11] the cylinder insert angle effect on the target [12] and OAR, [13]and the air pocket effects [14]. Few study has been done on the pre-simulation verification tolerances and the corresponding effects on OAR. In this study, our goals: 1. to statistically find out the achievable and practical simulation tolerances for HDR cylinder treatment using scout AP/LAT images; 2. to find out the corresponding dosimetry effects.

METHODS AND METHODS

Five previously treated vaginal cuff cancer patients were randomly selected. All of the patients had a prescription of 5 mm above the cylinder surface with 500 cGy per fraction for 5 fractions. The patients' general information is listed in table 1. The patients were scanned using GE lightspeed CT (computed tomography) simulator with a slice thickness 2.5 mm. The cylinder, rectum, bladder were contoured by a physician. The isodose 100% was normalized to the catheter points which were created with active catheter dwell positions with a distance of half of the cylinder diameter size plus 5 mm. The isodose 100% distribution was further optimization using Oncentra treatment planning system (Nucletron, an Elekta company, Atlanta, GA, version 4.1) graphical local optimization method. The 100% isodose line was dragged to conform to the catheter points and follow the cylinder tip curvature. Two scouts (anterior-posterior-AP and lateral-LAT direction) were taken during CT scan day. The dummy source was placed in the cylinder and the tip of the dummy source to the top of the pubic bone vertical distance on the AP scout was measured as baseline. The cylinder diameter was also measured for 2nd check of the applicator. The LAT dummy source angle relative to the horizontal line was also measured as baseline. A typical AP and LAT scout images were shown as Figure 1. For each fraction treatment, two similar scout images were taken to verify the insert angle, distance, and application diameter. The patient was then transferred using stretcher to the treatment room once the simulation was done and the physician approved for treatment.

In order to reconstruct the treatment for each fraction, the scout images including the baseline scouts were imported into Oncentra treatment planning system and the source were reconstructed. The reconstruction origin was the right femur bone center. The dwell position time and relative weight were the same as the plan. The reconstructed source coordinates were recorded. The planning source coordinates and the baseline source coordinates were then co-registered using three-dimensional rigid registration method as shown in equation (1).

Table 1: General patient information.

Patient ID	Age	Staging	Diameter (mm)	Active length (mm)
P1	67	T1 NX MX	35	40
P2	37	T1a N0 M0	30	40
P3	69	T1a N0 M0	35	45
P4	92	T2 NX MX	35	40
P5	64	T1a N0 M0	30	40

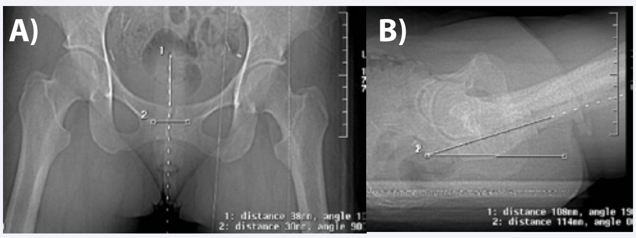

Figure 1 **A)** 3D view of the catheter reconstruction for treatment in AP direction. **B)** 3D view of the catheter reconstruction for treatment in LAT direction.

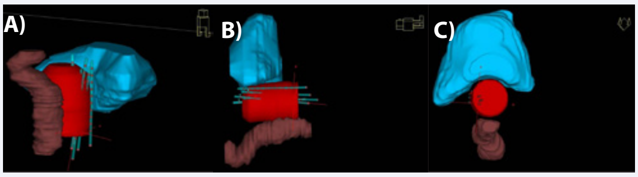

Figure 2 **A)** 3D view of the catheter reconstruction for treatment in PA direction. **B)** 3D view of the catheter reconstruction for treatment in Lateral direction. **C)** 3D view of the catheter reconstruction for treatment in Inferior-superior direction.

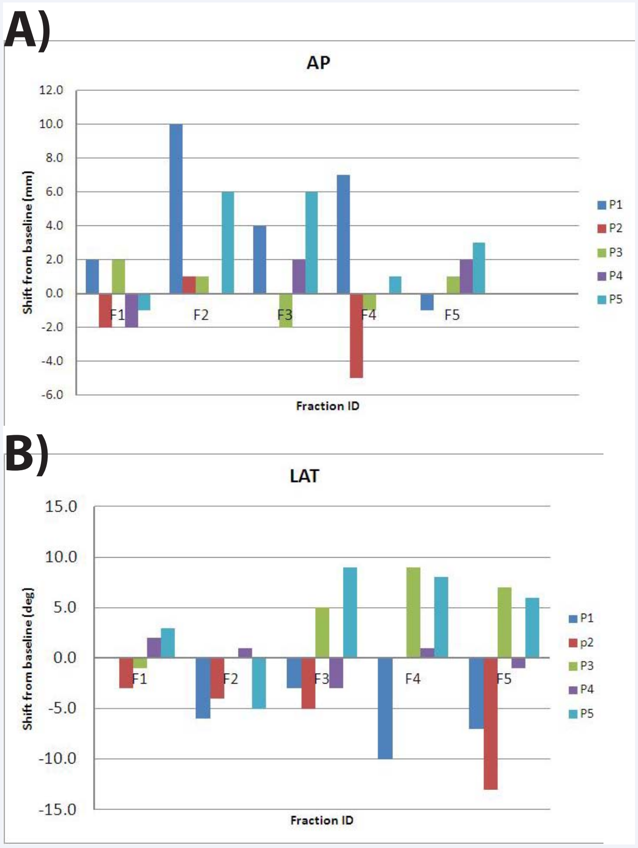

Figure 3 **A)** AP scout shift from the baseline for all five fractions and patients. **B)** LAT scout angle shift from the baseline for all five fractions and patients.

$$X' = RX + T \quad (1),$$

Where X is the reconstructed baseline source coordinates and X' is the planning CT coordinates. The rotation matrix R and transformation matrix T were then determined by using Singular Value Decomposition (SVD) method. Once the rotation and transformation were known, other fractions source coordinates were then able to be transferred into the planning CT coordinates. A full set treatment sources reconstruction in CT coordinates were illustrated in Figure 2. A dummy plan was then created with a prescription of 2500 cGy for 1 fraction. Each of the five reconstructed catheters was given the same dwell time as the plan. The cumulative dose was then computed. Since the reconstructed catheter 100% isodose may invade into either the bladder or rectum, only the median dose for the bladder and rectum were considered for relatively dosimetry effect.

Table 2: The median rectum and bladder dose difference between the plan and the dummy reconstructed deliver plan.

	Rectum – Plan %	Rectum -Deliver %	Difference %	Bladder- Plan %	Bladder-Deliver %	Difference %
P1	55.8	62.7	6.9	51.0	54.9	3.9
P2	66.4	75.4	9.0	47.9	47.1	-0.8
P3	66.3	66.6	0.3	62.8	65.9	3.1
P4	52.1	55.4	3.3	59.9	67.9	8.0
P5	48.0	62.0	14.0	35.7	17.9	-17.8

RESULTS

Figure 3 shows the AP and LAT scout image shifts for all five patients. The AP shifts were ranging from -5 mm. Table 2 shows the rectum and bladder median percentage dose difference between the plan and the dummy reconstructed delivered plan. The percentage difference can be ranging up 0.3%-14% for the rectum and -17.8%-8.0% for the bladder depending on the cylinder insert reproducibility.

Based on the statistics results from Figure 3 and table 2 and considering the convenience for the patient and treatment, we propose the pre-treatment simulation tolerances as: trying to maintain the cylinder in AP direction shift under 5 mm, and a warning zone is 5 mm-10 mm. Anything more than 10 mm shift may be adjusted or with both physician and physicist agreement. For the lateral angle, trying to maintain the angle difference under 5 degree and keep the 5-10 degree as warning zone. Anything more than 10 degree shifts may be adjusted for quality assurance purpose. With this tolerance setting, the bladder and rectum median dose can be controlled within tens of percentage, which may not cause serious complication for vaginal cuff HDR alone treatment. If the HDR treatment were followed with external beam treatment, a tighter tolerance may be necessary to avoid the warning zone. Due to the study limitation, the rectum and bladder maximum dose and DVHs were not available. However, the median doses were less affected by the source position errors and could also represent the dosimetry effects for the OAR.

CONCLUSION

In this study, we have done pre-treatment simulation quality assurance study using AP/LAT scout images. The tolerance for this pre-treatment simulation was proposed. The relative dosimetry effects for the rectum and bladder were reported.

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