Quantifying the clinical effect of ring applicator position corrections in the treatment of intracavitary Ir-192 HDR brachytherapy patients

Alison Marsh, MS, Andrew Farach, MD, Jarron Syh, MS, Ramiro Pino, PhD
Houston Methodist Hospital, Department of Radiation Oncology, Houston, TX

Abstract

This study seeks to quantify the dosimetric significance of making dwell position corrections during treatment of tandem and ring HDR brachytherapy. Clinically relevant parameters show no statistically significant difference between corrected and uncorrected plans.

Introduction

Vendor-provided guidelines recommend correcting dwell positions for Varian ring applicators for HDR brachytherapy. These corrections have been validated through imaging and video analysis and are currently the standard of practice for use of tandem and ring applicators for treatment of cervical cancer. The aim of this report is to study the dosimetric significance of these corrections and how they vary between different ring sets.

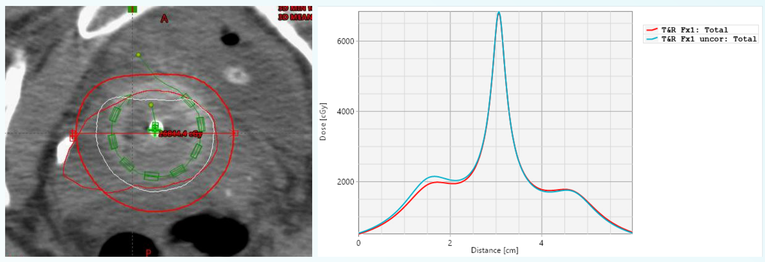

Figure 1: An example tandem and ring case. Uncorrected plan was calculated to simulate dose without dwell position corrections applied. Dose profile drawn from left to right across the tandem through the top of the ring cap shows that significant dose differences may be observed along the ring, particularly towards the end of the ring channel (~2Gy higher for a plan without applying corrections).

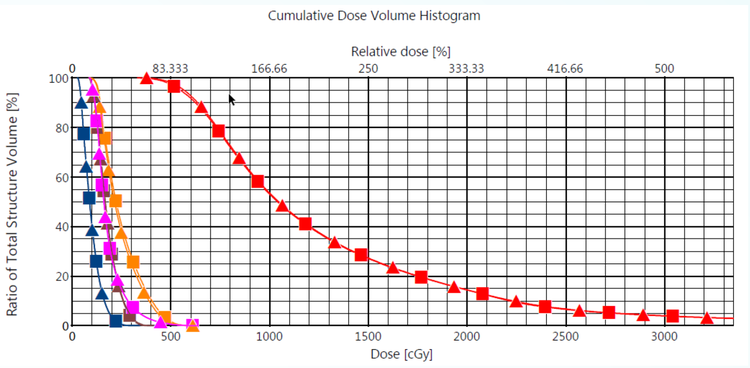

Figure 2: DVH comparison between corrected (squares) and uncorrected (triangles) plans show very little difference to the target and OARs. The only observable difference is found in the dose to the bladder which is hotter for the corrected plan.

Materials

Two clinical Varian tandem and 60º ring sets used for treatment with a VariSource afterloader were utilized in this study. Treatment plans were created in BrachyVision and calculated using the TG-43 formalism. Dwell position corrections were measured on digitized EBT3 film.

1. Varian Medical Systems. "R&T VS_2." 2010.

Methodology

Eleven cervical cancer patient plans treated in a one year period with the same T&R set were recalculated with and without the vendor-recommended dwell position corrections applied to the ring applicator in BrachyVision TPS. Prescription doses were 6 Gy/fraction to the physician-contoured HR-CTV. Dosimetric parameters were compared including HR-CTV coverage, D2cc of bladder, rectum, and sigmoid, and dose to point A. This data was also compared to the same data from eleven patient plans treated with a different T&R set.

Position corrections were measured separately for each ring set. Small variations in ring construction can lead to differences in the source path and, therefore, differences in the dwell position corrections. Two T&R sets were used in order to investigate the affect that varying corrections have on the results.

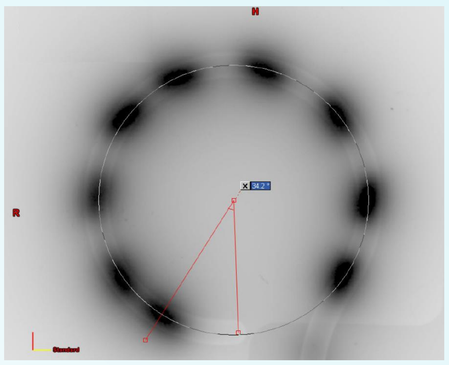

Figure 3: Film measurement of ring positions. Varian recommends measuring the angle each dwell position makes with the end of the applicator and using it to calculate the path length:

$$Path\ Length\ [cm] = \left(\pi * r * \frac{\alpha}{180°}\right) - SCDT$$

where r is the radius of the ring, α is the measured angle, and $SCDT$ is the source center distance from the applicator tip.
The delivered position is then:

$$Delivered\ Position = 120[cm] - Path\ Length[cm].$$[1]

Table 1. Ring position corrections

Set No.	Magnitude of Correction along Path Length [cm]							
#1	0.0	0.2	0.2	0.4	0.4	0.3	0.3	0.2
#2	0.1	0.1	0.2	0.3	0.4	0.3	0.2	0.1

Table 1: Ring position corrections were measured for two 60º ring applicators according to Varian-recommended guidelines. Corrections are the difference in the planned and delivered positions. The average correction for the first set was 0.25 cm and the average for the second set was 0.21 cm. All corrections are made towards the proximal direction.

In order to simulate the dose distribution as a result of not manually applying dwell position corrections, we used applicator-specific corrections as measured by the vendor-recommended method using film and Eclipse treatment planning system. Using these measurements, we determined the actual dwell positions that the source would go to if plans were sent to the HDR console without any corrections applied. These positions were then used to create dose distributions which show the result of not applying dwell position corrections. Dwell times and contours remained constant between compared plans.

Results

The average percentage absolute difference in HR-CTV coverage was 0.5%. The average percentage absolute difference in D2cc of the bladder, rectum, and sigmoid were 0.9%, 0.9%, and 0.5% respectively. The largest absolute difference in dose was 15cGy in D2cc to the bladder. The largest and only statistically significant average difference was found in the dose to Point A which ranged from -1.9% to 2.3%. Results for the second ring set were comparable with the average differences within a standard deviation from the original set.

Table 2. Absolute percentage differences between corrected and uncorrected dose distribution parameters for 11 tandem and ring patients

Statistics	HR-CTV D90 [%]	Bladder D2cc [%]	Rectum D2cc [%]	Sigmoid D2cc [%]	Point A Right [%]	Point A Left [%]
Mean ± SD	0.5 ± 0.5	0.9 ± 1.0	0.9 ± 0.6	0.5 ± 0.4	1.3 ± 0.5	0.9 ± 0.5
Range	-0.4 – 1.9	-3.4 – 0.9	-0.7 – 1.7	-0.4 – 1.1	0.4 – 2.3	-1.9 – -0.2
Mean Ratio: Corrected / Uncorrected	0.997 ± 0.006	0.994 ± 0.009	1.006 ± 0.012	0.997 ± 0.005	0.987 ± 0.005	1.009 ± 0.005
p-value	p = 0.15	p = 0.06	p = 0.13	p = 0.11	p < 0.001	p < 0.001

Table 2: Absolute percent differences between corrected and uncorrected coverage and normal tissue dose parameters were calculated using:
% Difference = |Uncorrected – Corrected| / Corrected * 100%.
Mean absolute percent differences range in magnitude from 0.5% to 1.3%. The only parameters which demonstrate statistical significance are the Point A values. Since the location of Point A is fixed to the position of the applicator itself, the change in the dose distribution due to shifts, and therefore the dose to Point A, always moved in the same direction for each patient, increasing for Point A right and decreasing for Point A left.

Table 3. Absolute differences between corrected and uncorrected dose distribution parameters for 11 tandem and ring patients

Statistics	HR-CTV D90 [cGy]	Bladder D2cc [cGy]	Rectum D2cc [cGy]	Sigmoid D2cc [cGy]	Point A Right [cGy]	Point A Left [cGy]
Mean ± SD	2.8 ± 3.1	4.1 ± 4.6	2.7 ± 1.8	1.5 ± 1.3	6.1 ± 2.8	4.3 ± 2.5
Range	-2.9 – 11.9	-15.0 – 4.7	-2.4 – 5.8	-1.5 – 4.8	1.9 – 9.7	-8.4 – -1.1

Table 3: Absolute differences between corrected and uncorrected coverage and normal tissue dose parameters was found by the following equation: Difference = |Uncorrected-Corrected|. Mean differences range in magnitude from 1.5 cGy to 6.1 cGy. The range of differences was found using: Difference=Uncorrected-Corrected in which the absolute value was not taken in order to highlight the direction in which these differences occurred. For all parameters except Point A, the differences occurred in both directions. The largest absolute difference was seen in the D2cc to the bladder with a difference of 15.0 cGy.

Conclusion

No studied parameter apart from dose to Point A showed statistically significant differences between corrected and uncorrected T&R plans for either studied ring set. Other sources of error such as contouring and manual correction of the dwell positions in HDR have the potential to be much larger than the differences found in this report. A full cost and benefit analysis of dwell position corrections is under further investigation.