An Approach to Improved MLC Transmission Modeling for Highly-Modulated Treatments in Pinnacle Treatment Planning System

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INTRODUCTION

Pinnacle Treatment Planning System (TPS) allows users to input MLC parameters to improve physics modeling[1,2]. Several authors have previously described methods and published data for MLC transmission[3,4,5,6,7,8]. However, this work demonstrates a simple and improved method for determining MLC parameters.

The purpose of this study was to develop a novel approach for determining optimum values for MLC transmission, additional interleaf leakage, and tongue and groove width that will improve modulated beam modeling in Pinnacle TPS v9.10 for 6MV, 6MV-FFF, 10MV, and 10MV-FFF photon beams.

METHODS and MATERIALS

Open and MLC closed fields were measured using EDR2 film for Varian TrueBeam Linac with Millennium 120 MLC. Calibration curves were used to convert the films from intensity to absolute dose. The ratio of MLC matrix to open matrix was calculated. The average of every column of data was determined along the direction of the MLCs. This resulted in a single average dose profile of interleaf leakage and MLC transmission. The peaks (interleaf leakage) and valleys (MLC transmission) were averaged together to get the final average interleaf leakage and MLC transmission. Finally, the tongue and groove width was estimated dosimetrically by the FWHM for each period. A final correction for additional interleaf leakage was applied to the model.

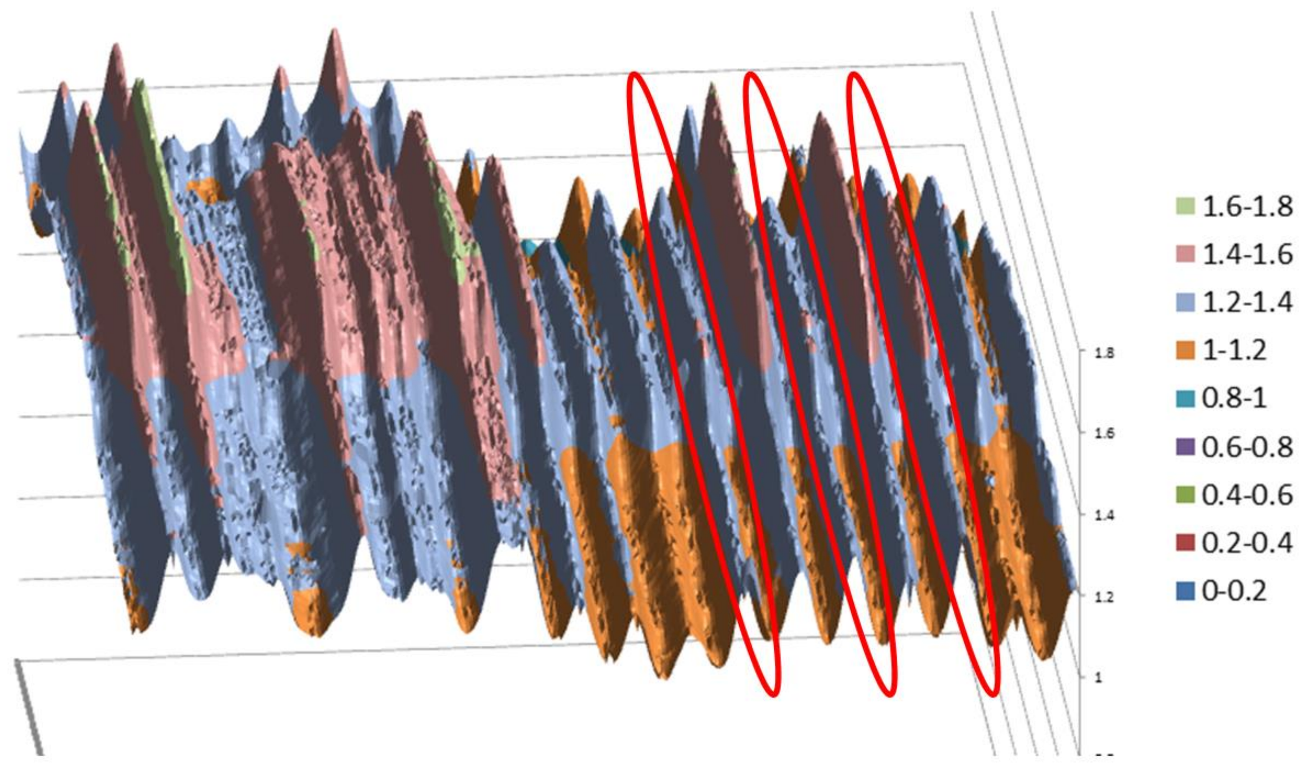

Figure 1: Shows an example of extracted matrix of transmission values from calibrated films. The units presented in this figure are percent transmission. This was created by the ratio of dose from MLC closed fields to open fields. The red ovals represent a few columns of MLC transmission that were averaged along the direction of the MLCs. The average of each column created the final average interleaf leakage and MLC transmission curve shown in figure 2.

Experimental outline

1. Measured open and MLC closed fields for specified energy using EDR2 film
   a) MLC close fields received 2000MU
   b) Open fields received 250MU

Experimental outline Cont.

2. Measured two calibration curves
   a) 0-110 cGy
   b) 0-385 cGy
3. Developed films
4. Cropped films
5. Applied calibration curve (0-110 cGy) to MLC closed films
6. Applied calibration curve (0-385 cGy) to open films
7. Extracted Matrix of dose values from calibrated films
8. Applied a multiplication factor of 8 to open film matrix
9. Calculated the Ratio of MLC matrix to open matrix
10. Removed the data for the edges (penumbra) of the film
11. Averaged every column (along the direction of MLC motion)
12. This resulted in a single average dose profile made of interleaf leakage and MLC transmission
13. The ridges (higher dose; interleaf leakage) and valleys (lower dose; MLC transmission) were then averaged together to get the final interleaf leakage and MLC transmission.

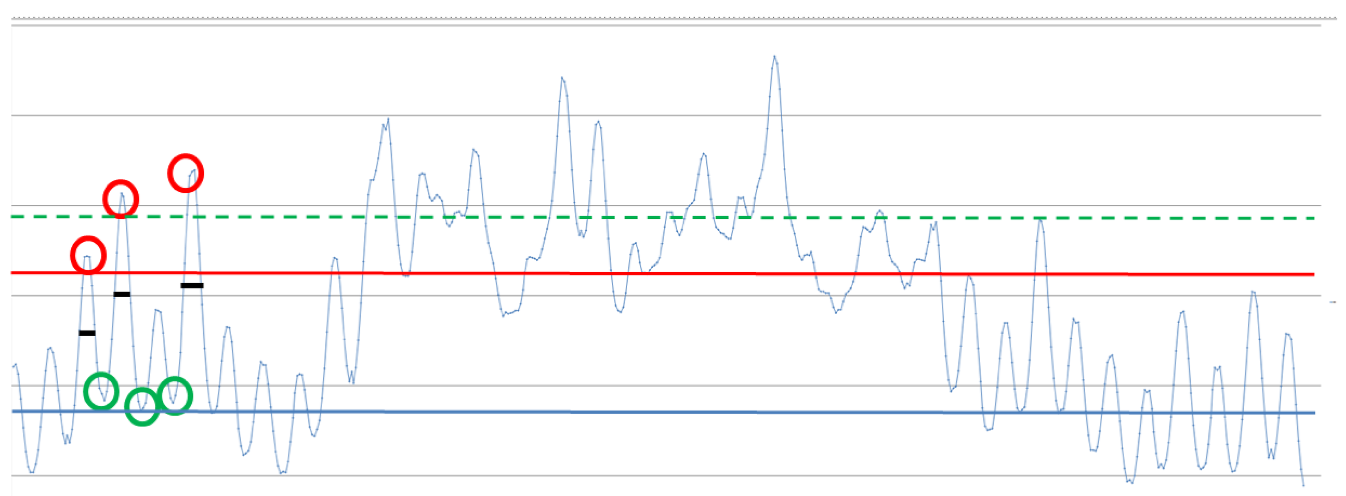

Figure 2:Shows the final average interleaf leakage and MLC transmission curve. All of the peaks (red circles representing interleaf leakage) and all of the valleys (green circles representing the MLC transmission) were then averaged to get the final average interleaf leakage and average MLC transmission for each energy studied. The black lines (full width half maximum of the peaks) were averaged across the curve to determine the average tongue and groove width. For TPS modeling the blue line is the "base line" and is defined by MLC transmission. The red line is the square root of the MLC transmission and is automatically applied in the Tongue and Groove width defined. The green line represents the sum of the blue and red line and can be further increased by increasing additional interleaf leakage.

RESULTS

We compared gamma pass rates from measurements of 14 VMAT arcs and 75 IMRT fields covering a range of anatomical sites. The new model was compared to the current model by analyzing the mean pass rate in percentage points. The most dramatic improvement in pass rates was observed in 10MV VMAT arcs with an improvement of 23.5 percentage points using gamma criteria of 2%/2mm without Van Dyk and the lowest improvement of 0.5 percentage points for 6MV-FFF VMAT using gamma criteria of 3%/3mm with Van Dyk. IMRT fields showed little improvement with minimal degradation of pass rates.

		Current Model	New Model
MLC Transmission			
	6X	0.01300	0.01210
	6FFF	0.01200	0.01016
	10X	0.01300	0.01570
	10FFF	0.01300	0.01230
Additional Interleaf Leakage		0.010	0.014
Tongue and Groove Width (cm)		0.04	0.13

Table 1:Comparison of our current clinical model parameters to the new model parameters as determined by our experimental method.

	Current model				New model			
VMAT (Sample Size N = 14 arcs)	2% / 2mm (no Van Dyk)	3% / 3mm (no Van Dyk)	2% / 2mm (w/ Van Dyk)	3% / 3mm (w/ Van Dyk)	2% / 2mm (no Van Dyk)	3% / 3mm (no Van Dyk)	2% / 2mm (w/ Van Dyk)	3% / 3mm (w/ Van Dyk)
6MV	70.5	84.6	81.0	95.2	80.3	91.7	90.0	98.0
			*(Pass Rate Change in % Points)		9.8	7.1	9.0	2.8
6MV-FFF	76.4	89.3	88.3	98.3	80.7	92.2	91.9	98.7
				*	4.3	2.9	3.6	0.5
10MV	57.4	74.3	66.2	88.4	80.9	92.8	90.6	98.1
				*	23.5	18.5	24.4	9.7
10MV-FFF (Sample Size N = 13 arcs)	71.2	86.0	83.8	96.4	81.5	93.2	92.3	98.6
				*	10.4	7.2	8.4	2.3
IMRT (Sample Size N = 75 Fields)								
6MV	90.7	97.8	95.8	99.3	91.5	97.3	95.2	99.5
				*	0.8	-0.4	-0.6	0.3
6MV-FFF	92.1	97.8	95.4	99.2	88.9	97.1	94.3	99.2
				*	-3.2	-0.7	-1.1	0.0
10MV	94.0	98.2	97.5	99.3	90.1	96.7	96.0	99.5
				*	-3.9	-1.5	-1.5	0.2
10MV-FFF (Sample Size N = 74 Fields)	94.4	98.3	97.1	99.4	91.5	97.4	96.0	99.5
				*	-2.9	-0.8	-1.1	0.1

Table 2: Analysis of mean gamma pass rates in percentage points sorted by technique and energy. VMAT arcs were measured using SNC ArcCHECK QA device. IMRT fields were measured using SNC MapCHECK 2 QA device. All measurements were analyzed using SNC Patient software v6.7.3 with 10% threshold. The results show an improvement in mean passing percentage points for highly modulated fields. Several VMAT arcs would not pass gamma analysis using 3%/3mm before implementing the new model data. Also observed was minimal degradation of mean gamma passing percentage points for lightly modulated IMRT fields. It was observed that fields with relatively low measurements using the current model were further decreased since the overall TPS calculation increased due to increasing transmission. This caused more failures as seen by decreased pass rates for some IMRT fields.

SUMMARY

This study has demonstrated a novel and thorough method for measuring and implementing improved values required by Pinnacle TPS. The results showed marked improvements in gamma pass rates for highly modulated fields with little change in pass rates for lightly modulated fields.

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