Commissioning a 2.5 MV Portal Imaging Beam in the Eclipse Treatment Planning System

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Spring Clinical Meeting of the American Association of Physicists in Medicine, Kissimmee, FL

March 30th – April 2nd, 2019 PO-BPC-Exhibit Hall-25

Introduction

A 2.5 MV portal imaging beam is available on the TrueBeam linac, which has been shown to have improved image quality compared to higher energy portal imaging beam lines, such as 6 MV [1,4]. To our knowledge, this imaging beam line has not been modeled by any commercial TPS. It has only been modeled by non-commercial Monte Carlo simulations [1].

The purpose of this work was to investigate the feasibility of the Eclipse TPS in modeling the 2.5 MV imaging beam. Two Eclipse algorithms were tested: Acuros XB and AAA.

Methods

Commissioning beam data

Standard beam commissioning data for the 2.5 MV beam were acquired on a TrueBeam linac at the University of Wisconsin-Madison Department of Human Oncology. Some characteristics of this beam are:

- Flattening filter free (FFF)
- $d_{max} \approx$ 0.60 cm
- Mean photon energy = 0.46 MV
- Maximum dose rate = 60 MU/min
- %dd(10cm) ≈ 52%

Beam model formation

Two dose calculation algorithms in Eclipse were tested using the same commissioning process:

- Anisotropic Analytical Algorithm (AAA) – a convolution/superposition (C/S) algorithm
- Acuros XB – a Linear Boltzmann Transport Equation (LBTE) solver

In addition to measured profiles and PDDs, the following data are required to commission both algorithms:

- Photon spectrum
- Mean radial energy curve
- Intensity profile
- Spot size X and Y
- Dosimetric leaf gap (DLG)
- MLC transmission

Validation Testing

The recommendations of Medical Physics Practice Guidelines (MPPG) 5.a were followed for validation [6]. A list of the tests used for these beam models are shown below:

- 5.1: Physics mode vs. planning module large fields
- 5.2: Clinical calibration reproducibility (Tolerance = 0.5%)
- 5.3: Measured vs. calculated small and large fields.
- 5.4-5.8: Basic photon tests measured in a water tank (**Figure 1**)
- 6.2: Cork heterogeneity test (**Figure 2**)

(5.1–5.3: Require only commissioning data)

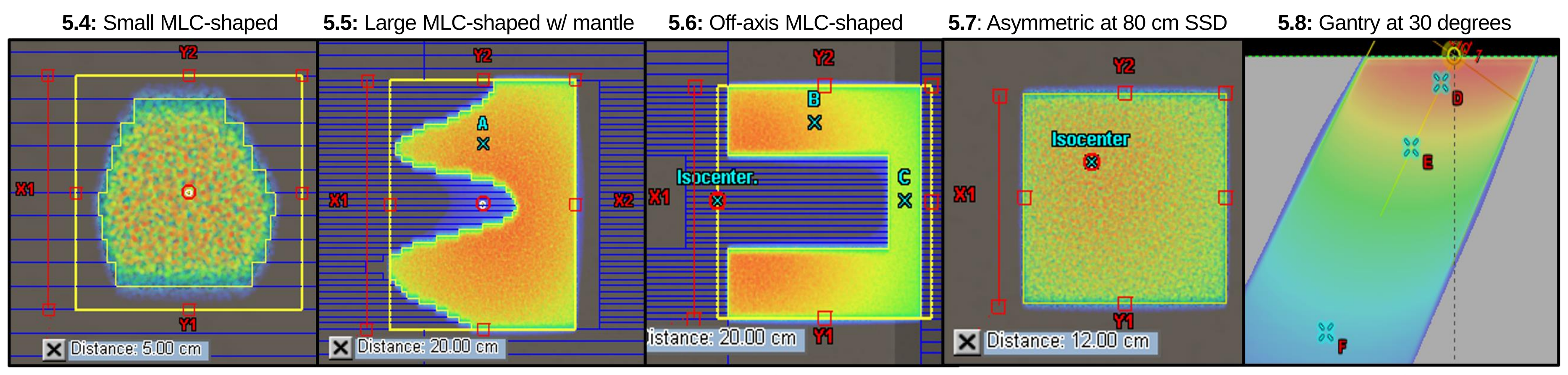

Figure 1: Beam apertures for Tests 5.4-5.8. MLC motion is in the crossline direction. Letters refer to profile acquisition points in Table 2.

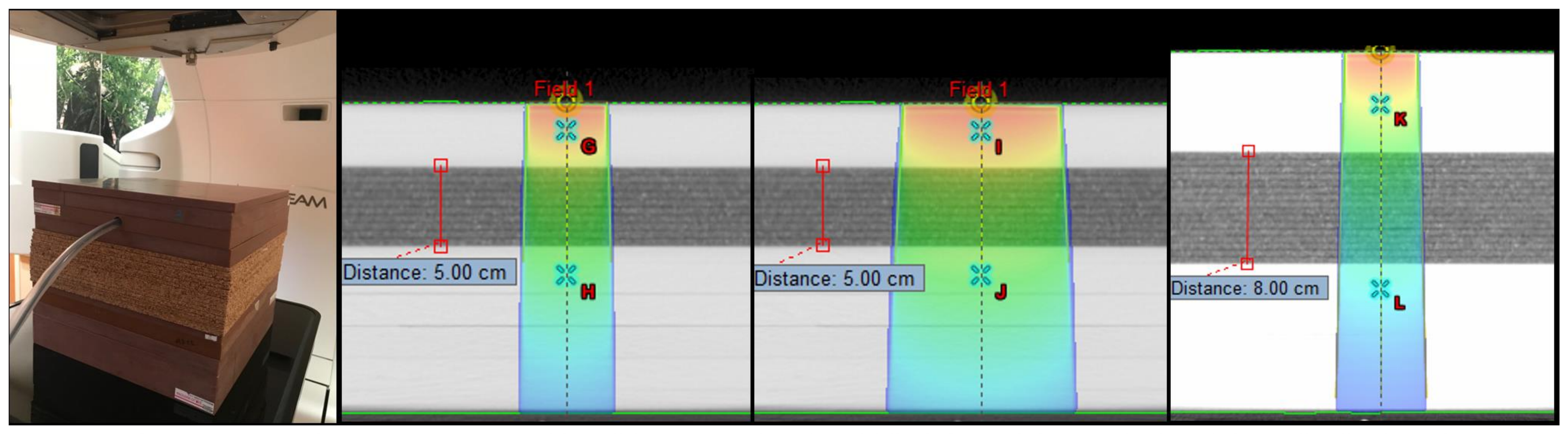

Figure 2: Setup for Test 6.2. Left – measurement with solid water and cork. Middle-left to Right – Calculated dose distributions for Setup 1 (5 cm thick cork, 5x5 cm²), Setup 2 (5 cm thick cork, 10x10 cm²), and Setup 3 (8 cm thick cork, 5x5 cm²). All setups are 100 cm SSD.

The following criteria were used to evaluate the profiles for Tests 5.4-5.8.

- Gamma pass rate with 2%, 2 mm global, and 3%, 3 mm global criteria
- Local dose-difference for PDDs and in-field profiles (2% tolerance)
- Global dose-difference for out-of-field profiles (3% tolerance)

For Test 6.2, the ratio of dose above the cork to the dose below the was computed for the measured and calculated data, as shown in Equation 1. The calculated ratio should match measured within 3% difference.

$$r = \frac{D_{above\ cork}}{D_{below\ cork}} \quad (1)$$

Results

Beam models

Several features of the 2.5 MV beam models are shown below, along with features from a 6 MV golden beam model from Varian.

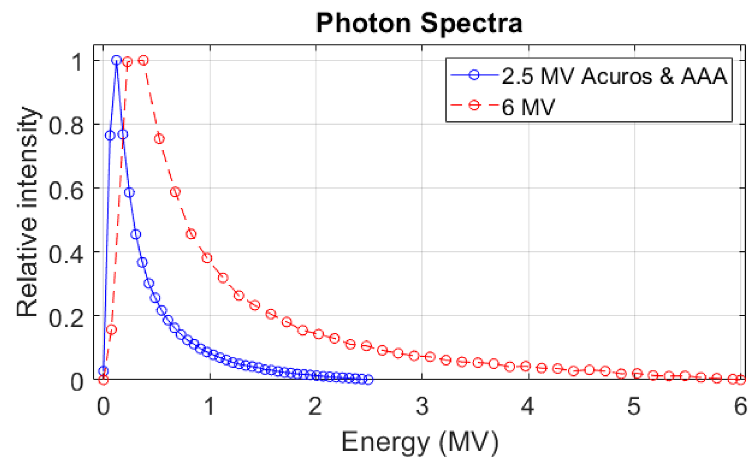

Figure 3: Photon spectra for 2.5 MV and 6 MV models.

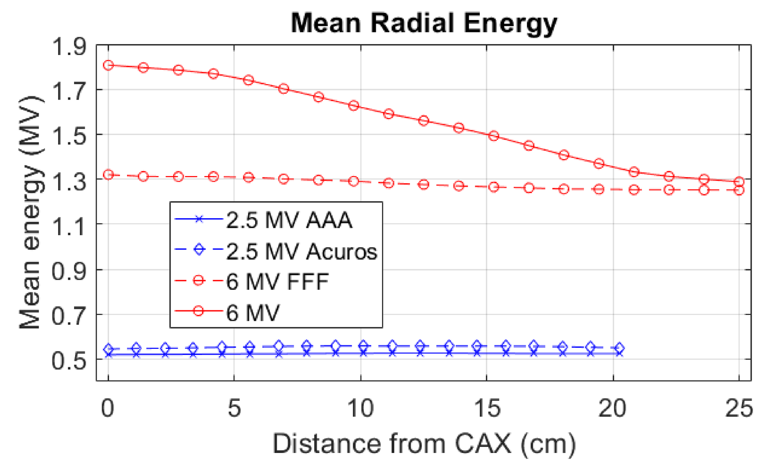

Figure 4: Mean radial energy curves for 2.5 MV and 6 MV models.

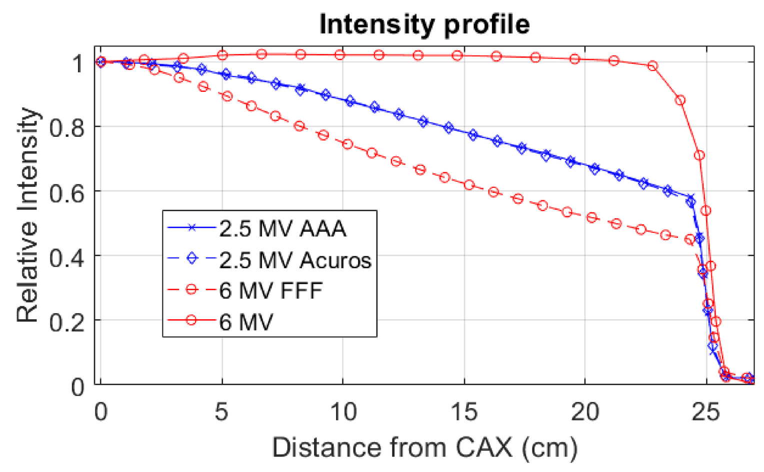

Figure 5: Intensity profiles for 2.5 MV and 6 MV models.

Table 1: Spot size parameters in the crossline (X) and Inline (Y) directions after optimization. Typical spot sizes are from [3].

	Spot X (mm)	Spot Y (mm)
Acuros 2.5 MV Optimal	0.8	2.4
AAA 2.5 MV Optimal	0.6	2.4
Typical therapeutic Acuros	1.0	1.0
Typical therapeutic AAA	0.0	0.0

Table 2: Measured MLC parameters for 2.5 MV and typical parameters for a 6 MV beam.

	2.5 MV	6 MV
MLC transmission	0.32%	1.1%
Dosimetric leaf gap	0.22 mm	1.5 mm

Table 3: Calculation times for a 10x10 cm² field, 50x50x50 cm² water and 1 mm calculation grid.

AAA	Acuros
36 seconds	9.5 minutes

Validation: Basic Photon Tests

The results from the photon tests are shown below.

- 5.1: Acuros and AAA both pass within in-field and out-of-field tolerance.
- 5.2: Acuros and AAA reproduce the clinical calibration condition to within 0.81%, and 0.06%, respectively. The dose difference for Acuros is greater than the recommended tolerance of 0.5%.
- 5.3: Acuros and AAA both pass within in-field and out-of-field tolerance.
- 5.4-5.8: See **Table 4**. The gamma pass rate using a 2%, 2 mm global criteria was >95% for 21 of 23 scans for Acuros and for 18 of 23 scans for AAA. The gamma pass rate using a 3%, 3 mm global criteria was >98% for all 23 scans for both Acuros and AAA.

Both algorithms under-estimate out-of-field dose, as seen in the literature for higher energy beams [5].

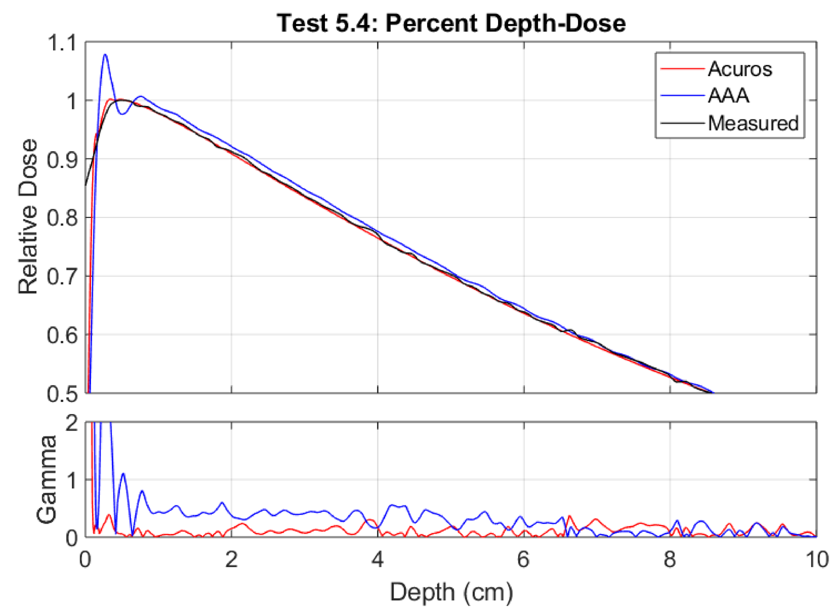

Figure 6: Example comparison for a PDD for Test 5.4. The gamma criteria is 2%, 2 mm, global. Note the instability of AAA in the buildup region.

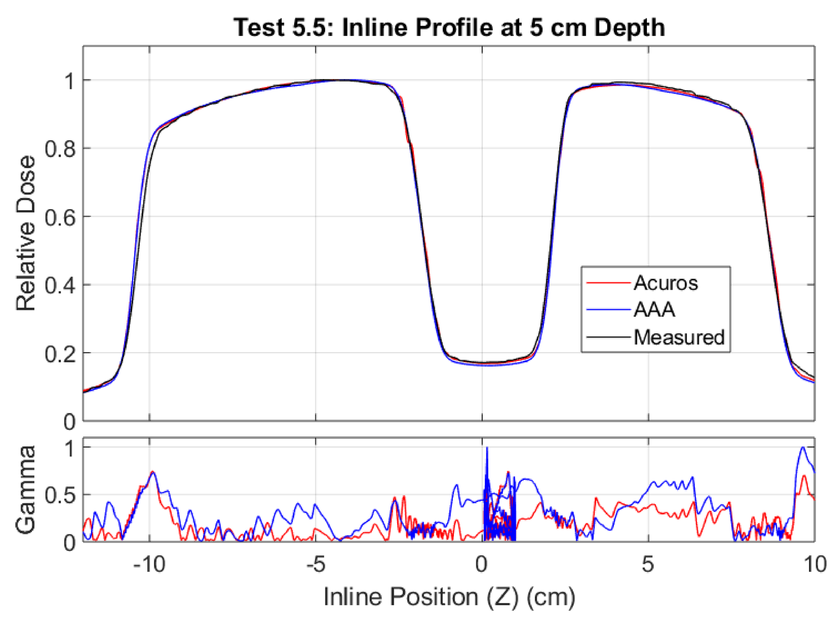

Figure 7: Example comparison for an inline profile at 5 cm depth for Test 5.5 (mantle). The gamma criteria is 2%, 2 mm, global.

Table 4: Gamma pass rates (2%, 2 mm global criteria) for Tests 5.4-5.8. Letters refer to positions in Figure 1.

		Depth, position	Acuros	AAA
5.4 Small MLC-shaped field	Crossline	5 cm, CAX	100.0	97.3
	Inline	1.5 cm, CAX	100.0	100.0
	Inline	5 cm, CAX	100.0	100.0
	Inline	15 cm, CAX	100.0	97.7
	PDD	CAX	99.7	98.7
5.5 Large MLC-shaped field with Mantle	Crossline	5 cm, CAX	98.4	93.4
	Crossline	5 cm, Point A	97.7	91.4
	Inline	1.5 cm, CAX	100.0	98.8
	Inline	5 cm, CAX	100.0	99.9
	Inline	15 cm, CAX	98.4	98.4
	PDD	Point A	99.3	98.6
5.6 Off-axis MLC-shaped field	Crossline	5 cm, Point C	97.7	95.5
	Crossline	5 cm, Point B	97.6	96.4
	Inline	1.5 cm, Point C	97.8	93.6
	Inline	5 cm, Point C	96.9	93.1
	Inline	15 cm, Point C	92.0	96.3
	PDD	Point B	99.1	98.7
5.7 Asymmetric field, 80 cm SSD	Crossline	5 cm, CAX	98.4	96.6
	Inline	1.5 cm, CAX	100.0	96.4
	Inline	5 cm, CAX	99.7	99.2
	Inline	15 cm, CAX	97.4	100.0
	PDD	CAX	99.3	98.4
5.8 30° oblique incidence	Crossline	5 cm, Point D	95.3	88.0
	Inline	1.5 cm, Point D	98.2	89.9
	Inline	5 cm, Point E	98.0	96.2
	Inline	15 cm, Point F	88.6	100.0
	PDD	CAX	98.4	97.6

Validation: Heterogeneity

Test 6.2 results are shown in **Table 5**. Point doses were measured in solid water at least 2 cm away from the cork to avoid the buildup region. The measured ratio was reproduced within 1% difference for Acuros and greater than 2.9% difference for AAA.

Future work will investigate dose calculation through a bone-equivalent heterogeneity in addition to cork.

Table 5: Percent difference of the measured and calculated ratio from Equation 1. Letters refer to positions in Figure 2.

	Measured Ratio	Acuros		AAA	
		Ratio	% Diff.	Ratio	% Diff.
Setup 1: D_G/D_H	2.28	2.26	-0.97	2.19	-4.17
Setup 2: D_I/D_J	1.77	1.77	0.05	1.71	-2.91
Setup 3: D_K/D_L	1.63	1.63	0.02	1.58	-3.18

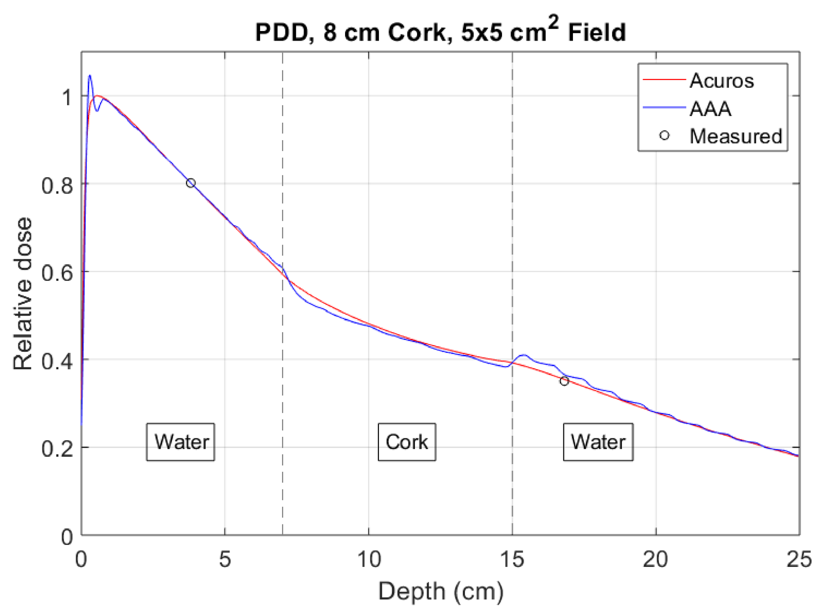

Figure 8: Measured data and PDD curves through the cork heterogeneity for Acuros and AAA. Values are dose to water.

Conclusion & Discussion

Both the Acuros and AAA algorithms were able to model this low-energy portal imaging beam. Table 6 summarizes the advantages of each algorithm. We recommend using Acuros if heterogeneity calculations will be performed.

The dose patients receive from routine portal images must be quantified to assess and manage risk. We validated that a commercial TPS can be used to perform regular patient-specific dose calculations for the 2.5 MV beam.

Table 6: Comparison of the two Eclipse algorithms in modeling the 2.5 MV imaging beam.

Acuros
• Lung heterogeneity calculations are more accurate • Higher gamma pass rates for profiles and PDDs for basic photon tests • PDD is more stable in the buildup region

AAA
• Clinical calibration condition reproduced more accurately (Test 5.2) • Calculation times are shorter

References

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Acknowledgements

The authors would like especially to thank:

- UW Medical Radiation Research Center (UWMRRC) students and staff
- Charles Matrosic, Daniel Anderson, and Dr. Larry DeWerd
- UW Accredited Dosimetry Calibration Laboratory customers for their continued support of the UWMRRC research program