Initial Evaluation of the Radixact Synchrony System

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INTRODUCTION

The Synchrony system allows for target tracking and motion compensation during treatment delivery on the Tomotherapy Radixact system. Montefiore Medical Center installed its clinical Synchrony system in September 2019.

Target motion in the sup/inf direction is compensated for via jaw tracking. Motion in the axial directions is compensated for via MLC offset in which the binary MLCs that are open are shifted, depending on the magnitude of the shift in the projection gantry angle.

AIM

Before clinical implementation, evaluation of the system performance was undertaken. Sinusoidal periodic motions were evaluated to separately evaluate the efficacy of jaw-based motion correction, MLC-based motion correction and the two combined.

METHOD

This study evaluates the accuracy of the Synchrony motion correction for the "respiratory" and "respiratory with fiducials" tracking modes using a Delta4 phantom and Hexamotion stage. EBT3 film was also used to allow for increased resolution and comparison to Delta4 values.

For both respiratory models three LED's act as an external surrogate allowing a motion model to be created. This model is constantly updated as kV images are acquired before and during the treatment.

Custom inserts were designed, and then 3D printed, that allow for target tracking using both a dense silicon rubber plug and triangular fiducial arrangement. The planned dose was delivered to a stationary phantom and a moving phantom both with and without motion correction enabled.

The dose delivery changes were evaluated using the gamma index (2%, 2 mm, 10% threshold) for the Delta4 and film placed in horizontal and vertical orientations. 1D motions in the Sup/Inf direction (y direction) only are compensated for with jaw positioning corrections. Motion in the axial plane (x-z direction) only are compensated for with MLC correction. Each type of motion was evaluated separately, and combined motions in both the y and x-z planes were evaluated with varying breathing periods.

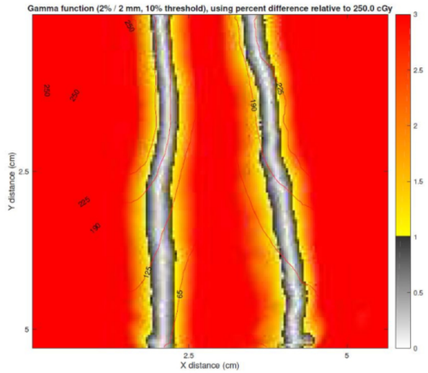

Figure 1. Gamma evaluation of a horizontal film for a 15 mm amplitude y direction motion **without** motion correction

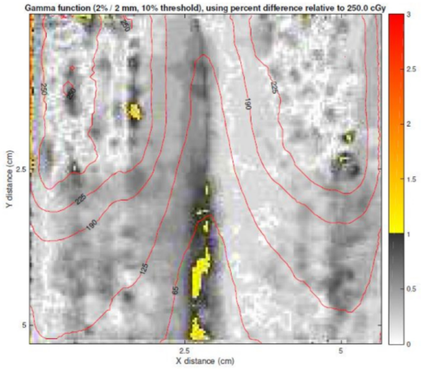

Figure 2. Gamma evaluation of a horizontal film for a 15 mm amplitude y direction motion **with** motion correction

Horizontal Film

Y Motion (mm)	Uncorrected	Corrected	Difference
2.5	93.9	84.8	-9.1
5	76.3	99.4	23.1
7.5	33.5	99.2	65.7
10	29.3	94.4	65.1
12.5	15	95.6	80.6
15	12.7	98.7	86

XZ Motion (mm)	Uncorrected	Corrected	Difference
3	95.7	99.5	3.8
6	99.4	98.6	-0.8
9	93.3	94.1	0.8
12	91.7	93.4	1.7
15	86.6	94.2	7.6

Table 1. 1D motion Respiratory Tracking results

Vertical Film

Y Motion (mm)	Uncorrected	Corrected	Difference
2.5	96.9	99.5	2.6
5	65.7	98.9	33.2
7.5	35.2	98.2	63
10	21.9	98.3	76.4
12.5	17.5	95.9	78.4
15	13.2	72.1	58.9

XZ Motion (mm)	Uncorrected	Corrected	Difference
3	80.1	94.7	14.6
6	92.7	98.7	6
9	97.3	97.9	0.6
12	87.9	98.1	10.2
15	81.4	97.4	16

Table 2. 1D motion Respiratory Tracking results

Delta4

Y Motion (mm)	Uncorrected	Corrected	Difference
2.5	95.4	99.8	4.4
5	83.4	100	16.6
7.5	41.4	99.4	58
10	27.3	99.8	72.5
12.5	19	100	81
15	16.8	100	83.2

XZ Motion (mm)	Uncorrected	Corrected	Difference
3	100	100	0
6	97.4	100	2.6
9	92.6	99.8	7.2
12	87.4	99.4	12
15	82.8	100	17.2

Table 3. 1D motion Respiratory Tracking results

Delta4

Y Motion (mm)	Uncorrected	Corrected	Difference
2.5	98.1	100.0	1.9
5	87.6	100.0	12.4
7.5	52.4	100.0	47.6
10	30.5	100.0	69.5
12.5	24.7	98.1	73.4
15	18.1	100.0	81.9

XZ Motion (mm)	Uncorrected	Corrected	Difference
3	100.0	100.0	0.0
6	94.8	100.0	5.2
9	87.1	99.8	12.7
12	83.2	99.6	16.4
15	77.6	99.1	21.5

Table 4. 1D motion Respiratory with Fiducial Tracking results

Delta4

Y Motion (mm)	XZ Motion (mm)	Period (s)	Uncorrected	Corrected	Difference
10	3	4	28.5	100	71.5
10	3	6	31.3	100	68.7
10	6	4	25.7	100	74.3
10	6	6	29.1	100	70.9
15	6	6	14.5	98.9	84.4
15	12	6	16.3	98.9	82.6

Table 5. 3D motion Respiratory Tracking results

Tables 1-5 show the gamma criteria passing percentages (2%, 2 mm, 10% max dose threshold) for various motion types and breathing periods

RESULTS

For treatment deliveries with uncorrected motion the gamma pass rates clearly show the need for target motion compensation. With increasing phantom motion the delivered dose distribution became increasingly distorted, reflected in low gamma pass rates. For the "respiratory" tracking mode Delta4 data shows an increase in pass rates of 4.4 % for 2.5 mm y direction motion, 16.6% for 5 mm motion and an average increase of 74% for motions ≥7.5 mm. For x-z motions a benefit was found when the motion exceeded the MLC leaf width of 6 mm at isocenter, with an average increase in pass rate of 9.8%. Analysis of film data shows similar improvement.

For "respiratory with fiducial" tracking mode Delta4 data shows an increase in pass rates of 1.9% for 2.5 mm y direction motion, 12.4% for 5 mm motion and an average increase of 68.1% for motions ≥7.5 mm. For x-z motions an average increase in pass rate of 14.0% was found.

For 3D motions with different respiratory periods there was a greater improvement for plans with a faster respiratory period. Measured pass-rates using the Delta4 phantom were above 98% for all corrected plans. Even with a more generous 5% / 5 mm criteria, all motions in the y direction >5.0 mm resulted in a failing gamma analysis (<90% of points passing).

CONCLUSIONS

These results clearly show the benefit of jaw tracking using Synchrony and to a lesser extent the benefit of MLC tracking. The results show a larger deviation in delivered dose distributions for target motion in the y direction only when compared to motion in the x-z plane only. Due to the helical nature of the Radixact delivery, dose deposition is less sensitive to target motion in the x-z plane.

The ability of the synchrony system to continuously deliver radiation to the exact target position, without the need to pause with the patients breathing cycle, is a clear advantage and improvement upon existing techniques.

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