



Introduction

Magnetic Resonance Imaging Guided Linear Accelerators (MR-Linac) require development of MR-compatible equipment for machine and patient-specific quality assurance (QA). The way the equipment manufacturers are addressing this new paradigm is through the update of their non-MR compatible products to MR-compatible. That is the case of the Arc Check from Sun Nuclear, Octavius from PTW and Delta4 from ScandiDos.

In this work for two available in the market devices, we characterized the influence of detector design and geometry in a low magnetic field on the results for patient specific quality assurance.

Methods

A commercial single plane ionization array (Octavius 1500, non 4D) and two planes orthogonal diode arrays (Delta4) were calibrated and implemented in a clinical MR-guided radiotherapy (MRgRT) program. Fourteen plans to treat different anatomical sites were selected to show the results of the study. The plans were developed using the ViewRay MRIdian planning system asking for a wide range of gantry angles and beams segments sizes. Patient specific QA plans were generated for the Octavius 1500 and for the Delta4. For the Gamma Index Analysis 2%/2mm criteria were used with a threshold of 90%.

Patient	Site	Octavius		Delta4
		Octavius @ 2/2 without cropping	Octavius @ 2/2 with cropping	Gamma Index @2%
1	Adrenal SBRT	89.10%	92.70%	93.80%
2	LT Adrenal SBRT	83.50%	96.60%	98.50%
3	SBRT Pancreas	95.10%	97.90%	97.20%
4	Lung LT SBRT	87.10%	95.50%	97.90%
5	Pancreas IMRT	93.30%	97.50%	94.50%
6	Liver SBRT	89.80%	99.20%	99.30%
7	Abdomen 35Gy	88.10%	99.60%	99.30%
8	Main Bronchus	79.60%	93.10%	97.60%
9	Pancreas	82.30%	93.00%	92.40%
10	Pancreas SBRT	74.70%	96.80%	95.20%
11	LT Abdominal Wall	85.80%	89.60%	96.40%
12	Pancreas SBRT	68.00%	98.90%	97.80%
13	Pancreas Boost	70.70%	69.00%	95.90%
14	Pancreas	89.00%	98.00%	94.70%

Table 1. Results of the patients QA for different treatment sites using 2%/2mm criteria for the Gamma Index with 90% threshold. In red the failing tests

Results

The Octavius 1500 showed an angular dependence. We found that a region of interest (ROI) excluding the peripheral detectors needs to be defined. That means, the area of analysis has to be cropped in order to perform in comparison with the Delta4. For the cropped area, 12 of 14 results between both devices are comparable. No restrictions in the couch position when the Delta4 was found. In some cases the Octavius 1500 could not be used because the couch should be positioned outside the allowable range. For the Delta4 the pass rate was above 92% and all plans passed the test. For the Octavius, without cropping, only 2 of 14 plans passed. With cropping, 2 plans of 14 failed.

Administrative Data
 Institution: Miami Cancer Institute
 Physicist: TR/DA
 PatientID: [redacted]
 Patient Name: [redacted]
 Comment: 2/2 not crop

Gamma 2D - Parameters
 2.0 mm Distance- To- Agreement
 2.0 % Dose difference with ref. to max. dose of calculated volume
 Suppress dose below 10.0 % of max. dose of calculated volume
 Option "Use 2nd and 3rd pass" selected

Statistics
 Number of Dose Points: 1,405
 Evaluated Dose Points: 538 (38.3 %)
 Passed: 473 (87.9 %)
 Failed: 65 (12.1 %)
 Result: 87.9 % (Yellow)

Settings
 Passing criteria: Gamma ≤ 1.0
 Green: 90.0 % to 100.0 %
 Yellow: 75.0 % to 90.0 %
 Red: 0.0 % to 75.0 %

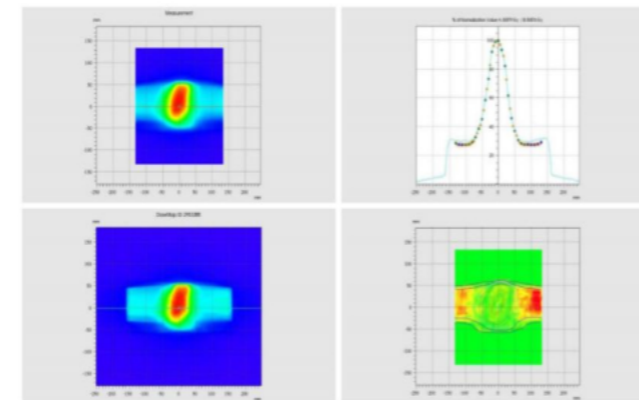


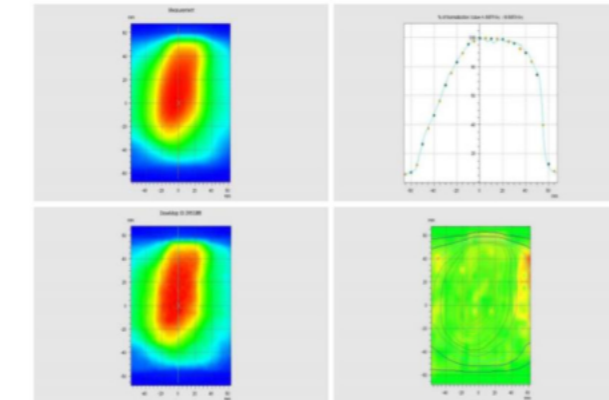
Figure 1. Illustration of the Octavius angular dependence. On the left, no ROI is defined. On the right, a ROI is defined to exclude the peripheral detectors

Administrative Data
 Institution: Miami Cancer Institute
 Physicist: TR/DA
 PatientID: [redacted]
 Patient Name: [redacted]
 Comment: [redacted]

Gamma 2D - Parameters
 2.0 mm Distance- To- Agreement
 2.0 % Dose difference with ref. to max. dose of calculated volume
 Suppress dose below 10.0 % of max. dose of calculated volume
 Option "Use 2nd and 3rd pass" selected

Statistics
 Number of Dose Points: 324
 Evaluated Dose Points: 278 (85.8 %)
 Passed: 276 (99.3 %)
 Failed: 2 (0.7 %)
 Result: 99.3 % (Green)

Settings
 Passing criteria: Gamma ≤ 1.0
 Green: 90.0 % to 100.0 %
 Yellow: 75.0 % to 90.0 %
 Red: 0.0 % to 75.0 %



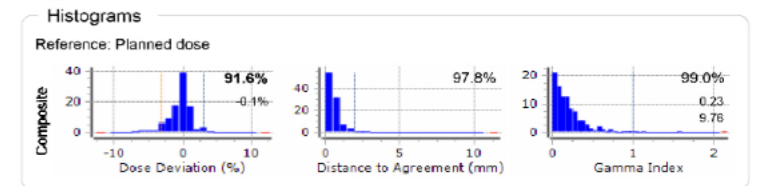
Conclusions

The Delta4 performed better than the Octavius 1500. No crop of the detectors area was necessary when the Delta4 was used, allowing the analysis in the low dose, low gradient region. The Delta4 allows the analysis in two orthogonal planes with higher spatial resolution (0.5mm).

Treatment Summary

Radiation Device: 206-TPS-03
 Temperature: 20.7 °C
 Reference: Planned Dose

Beam	Gantry	Energy	Daily corr factor	Norm dose	Det within acceptance	Median dose dev
Composite				15.47 Gy	91.6%	0.23
Beam 1_1	0°	6 MV	1.000	1.52 Gy	97.8%	99.0%
Beam 2_2	14°	6 MV	1.000	0.95 Gy		-0.1%
Beam 3_3	29°	6 MV	1.000	0.84 Gy		
Beam 4_4	43°	6 MV	1.000	1.55 Gy		
Beam 5_5	58°	6 MV	1.000	2.32 Gy		
Beam 6_6	72°	6 MV	1.000	1.45 Gy		
Beam 7_7	86°	6 MV	1.000	3.59 Gy		
Beam 11_8	144°	6 MV	1.000	1.52 Gy		
Beam 12_9	158°	6 MV	1.000	2.20 Gy		
Beam 13_10	173°	6 MV	1.000	2.79 Gy		
Beam 14_11	187°	6 MV	1.000	0.28 Gy		
Beam 15_12	202°	6 MV	1.000	1.38 Gy		
Beam 16_13	216°	6 MV	1.000	2.05 Gy		
Beam 20_14	274°	6 MV	1.000	2.14 Gy		
Beam 21_15	288°	6 MV	1.000	2.09 Gy		
Beam 22_16	302°	6 MV	1.000	0.54 Gy		
Beam 23_17	317°	6 MV	1.000	0.32 Gy		
Beam 24_18	331°	6 MV	1.000	0.27 Gy		
Beam 25_19	346°	6 MV	1.000	0.33 Gy		



Gamma Index Evaluations

DTA Pass Rates [%] Reference: Planned dose

DTA	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%	4.5%	5.0%
5.0 mm	99.5	99.5	99.7	99.7	99.7	99.7	99.7	99.7	99.7	99.7
4.5 mm	99.5	99.5	99.5	99.7	99.7	99.7	99.7	99.7	99.7	99.7
4.0 mm	99.2	99.6	99.6	99.6	99.6	99.6	99.6	99.6	99.6	99.6
3.5 mm	98.7	99.0	99.0	99.5	99.5	99.5	99.5	99.5	99.5	99.5
3.0 mm	98.4	99.0	99.0	99.2	99.2	99.5	99.5	99.5	99.5	99.5
2.5 mm	98.2	98.4	98.7	98.7	99.0	99.2	99.5	99.5	99.5	99.5
2.0 mm	97.1	97.4	98.2	98.2	98.4	98.0	98.5	98.5	98.5	98.5
1.5 mm	94.0	95.0	96.3	97.6	98.2	98.4	98.7	99.2	99.5	99.5
1.0 mm	88.8	90.3	92.1	93.7	95.5	96.8	97.4	97.5	97.7	97.8
0.5 mm	65.9	76.6	83.5	87.1	91.7	94.5	95.9	97.1	97.1	97.6

Parameter Definitions & Acceptance Criteria, Detectors

Parameter	Selected Detectors	Δ Dose	Δ Dist	Acceptance Limits
Dose Deviation	Dose from 10% to 500%	n.a.	n.a.	95% within ±3.0%
Dist to Agreement	Gradient ≥= 1%/mm	n.a.	n.a.	95% with DTA ≤= 2.0 mm
Gamma Index	Dose from 10% to 500%	±3.0%	2.0 mm	95% with gamma ≤= 1

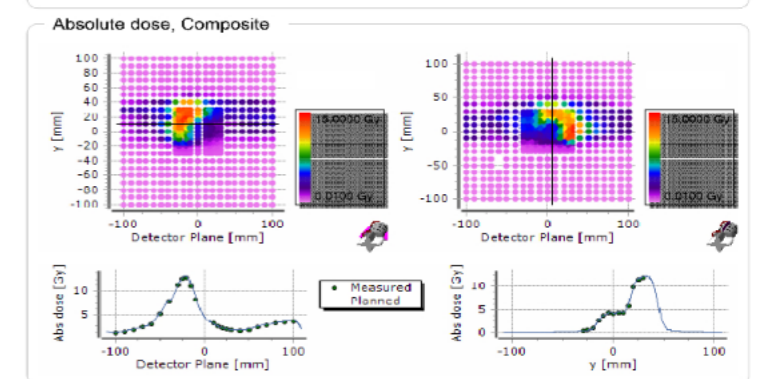


Figure 2. Report generated by Delta4. Histograms for dose deviation, DTA, Gamma Index and profiles (horizontal and vertical)