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Validation of the RayStation Treatment Planning System for IMRT Treatments on the 0.5 T Biplanar Linac-MR Hybrid (Aurora-RT)

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ABSTRACT

Purpose: To optimize and validate the treatment planning system (TPS), RayStation 11B, for the IMRT treatment on the 0.5 T Biplanar Linac-MR (Aurora-RT).

Methods: Raystation 11B has previously been commissioned for 3D-CRT treatments. MLC parameters in the TPS (leaf transmission, leaf offset, tongue and groove) are optimized by using an established formalism requiring a series of symmetric and asymmetric sweeping gap measurements and MLC open/closed measurements. Leaf tip width is not modeled due to the non-rounded MLC leaf tip design. Magnetic field effects are not explicitly modeled. Step and Shoot IMRT plans are generated in TPS based on standard TG119 requirements and constraints. Additionally, 8 mock prostate plans (5-field Step and Shoot) are generated based on PROFIT dose constraints. Patient prostate plans are assessed by a radiation oncologist. PSQA plans for TG119 and patient plans are recalculated and delivered on the Octavius 1500 MR phantom.

Results All planning constraints are met for TG119 plans except for the "hard" C-Shape plan. For PSQA evaluation, TG-119 plans yield gamma pass rate of > 97.2% at 3%/3mm, and a gamma pass rate of >93.0% at 2%/2mm. The lowest rates are Head & Neck and Multi Target plans. 8 mock prostate treatments are generated using the 5 field IMRT technique based on the PROFIT protocol, meeting dose constraints and deemed clinically acceptable by the radiation oncologist. PSQA for the 5 field prostate plans yields average pass rates of 99.9% at 2%/2mm.

Conclusion: The current Linac-MR MLC design is adequately modeled in RayStation 11B for accurate step-and-shoot IMRT plans. For our 8 mock patients, clinically acceptable 5 field plans are generated in the RayStation 11B treatment planning system, with an excellent PSQA pass rate of ~99.9% at 2%/2mm, despite not explicitly modeling for magnetic field effects.

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INTRODUCTION

- The 0.5 T Biplanar Linac-MR, a.k.a. Aurora-RT, (Figure 1) is vendor neutral when it comes to treatment planning system.
- RayStation 11B (RaySearch Laboratories) TPS, allows the user to incorporate the unique features of the Aurora RT (i.e. SAD = 120 cm, single jaw, etc.)
- Currently, Raystation 11B allows for Step and Shoot IMRT (sIMRT) delivery on the Aurora-RT.
- **Goal: To generate and optimize a RayStation beam model with MLC parameters suitable for sIMRT treatment for the Aurora-RT and validate using PSQA metrics.**

METHODS AND MATERIALS

- RayStation beam modeling is done using standard open field measurements (i.e. %dd curves, profiles measured for various field sizes and depths).
- MLC parameters (T&G factor) are optimized using the method proposed by Saez et al [1]. requiring a series of asymmetric sweeping gap measurements.
- Optimized MLC parameters are: MLCx offset, -0.05 cm, Leaf Tip Width = 0 cm, Tongue and Groove = 0.036 cm.
- sIMRT validation is done using TG-119 guidelines (7/9 field sIMRT on C Shape, C Shape hard, Head and Neck, Multi Target, Prostate scenarios).
- 5 Field sIMRT technique is used to generate PROFIT plans (6000 cGy in 20 Fractions) for localized prostate cancer patients. The treatment plans are reviewed by the Radiation Oncologist.
- TG119 plan are evaluated against the constraints as provided in the report, whereas the 5 field prostate plans are evaluated against PROFIT dose constraints.
- PSQA plans are generated for all plans and evaluated on a per-field basis, using gamma criteria of 3%/3mm and 2%/2mm.
- PSQA plans are delivered on the Octavius 1500 MR phantom with gantry angle set to zero, with ~3 cm polystyrene build up.

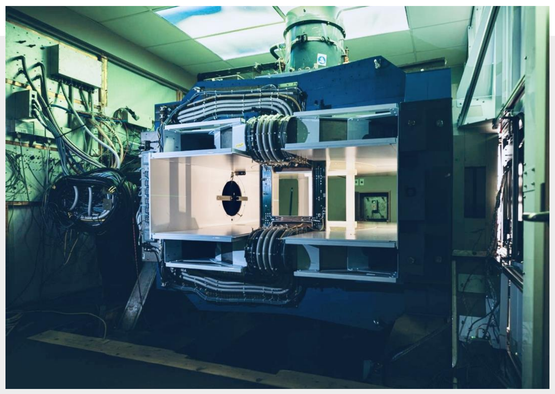

Figure 1. The Aurora-RT (0.5 T biplanar Linac-MR) behind the panels.

RESULTS

- TG-119 plans passed all required planning metrics, with the exception for "C-Shape hard" plan. PSQA gamma pass rates for 3%/3mm and 2%/mm are shown in Table 1. All plans passed on 3%/3mm criterion (> 97.4%). For 2%/2mm, C Shape, C Shape hard and Prostate passed all fields. For Head & Neck, Multi Target some fields in tolerance (> 93%).
- For the 8 Prostate patients, the 5 field sIMRT plans on the Aurora passed all clinical metrics, and all plans are evaluated as clinically acceptable by the radiation oncologist. PSQA pass rates are > 98.6% at 2%/2mm. Mean pass rate, 99.9%

Table 1., PSQA gamma pass rates for TG-119 sIMRT plans (Green = Pass, > 95%; Yellow: Tolerance, 90-95%)

	C Shape		C Shape Hard		Head & Neck		Multi Target		Prostate	
	3%/3mm	2%/2mm	3%/3mm	2%/2mm	3%/3mm	2%/2mm	3%/3mm	2%/2mm	3%/3mm	2%/2mm
Field 1	99.4	98.1	100.0	99.2	100.0	100.0	98.0	95.4	100.0	100.0
Field 2	99.2	95.0	100.0	100.0	100.0	99.2	97.2	93.3	100.0	100.0
Field 3	97.8	96.6	100.0	100.0	97.8	93.4	97.5	93.0	100.0	100.0
Field 4	100.0	99.3	100.0	98.2	99.5	97.5	99.0	95.3	100.0	99.1
Field 5	100.0	99.4	100.0	98.7	98.6	95.0	98.0	96.5	100.0	100.0
Field 6	99.3	96.6	100.0	100.0	98.6	98.1	98.3	93.6	100.0	100.0
Field 7	98.1	96.2	100.0	100.0	99.1	96.7	98.5	97.5	100.0	100.0
Field 8	100.0	95.8	100.0	98.6	100.0	96.0				
Field 9	100.0	97.7	100.0	100.0	100.0	100.0				

Table 2. 5 Field sIMRT Prostate, PSQA Gamma pass rate (Top) and plan dose metrics (Bottom)

6000cGy in 20 Fx	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6	Patient 7	Patient 8
5 Field sIMRT Prostate	PSQA Metrics: 2% / 2mm Gamma (QA Phantom: Octavius 1500 MR)							
Field 1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Field 2	99.2	100.0	100.0	100.0	100.0	100.0	100.0	99.1
Field 3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.6
Field 4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Field 5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Plan Dose Metric (cGy)							
PTV60 D99 > 5700 cGy	5855	5824	5940	5920	5773	5800	5808	5761
PTV60 D95 > 6000 cGy	6000	6000	6000	6000	6000	6000	6000	6000
PTV60 D1 < 6300 cGy	6208	6229	6137	6152	6274	6163	6218	6251
CTV60 D99 > 6000 cGy	6011	6016	6009	6012	6030	6018	6021	6032
Rectal Wall D30 < 3700 cGy	3201	2971	2942	3005	2319	2592	2661	3539
Rectal Wall D50 < 4600 cGy	4543	4451	4128	4123	3342	3987	4320	4436
Bladder Wall D30 < 3700 cGy	3430	2738	3107	2738	3494	3177	3366	3245
Bladder Wall D50 < 4600 cGy	4371	4119	4202	4210	4503	4578	4440	4478

DISCUSSION

- Magnetic field effects are not explicitly modeled in RayStation 11B. However, the 0.5 T parallel magnetic field does not have similar dose perturbation effects as compared to a perpendicular fields [2], such as the Electron Return Effect and shifting of crossplane beam profiles.
- 0.5 T parallel B does not have discernable dosimetric impact on the PSQA measurements (Octavius 1500 MR, polystyrene buildup)
- Our TG119 PSQA metrics indicate that Raystation 11B can accurately model the Aurora-RT's MLC for sIMRT planning.
- For localized prostate cancer, a simple 5 field IMRT technique generated good quality plans on the Aurora-RT that meet clinical constraints and yield excellent PSQA metrics for our 8 patients.
- Surface Dose: Caution is warranted as the 0.5 T parallel have been shown to lead to surface dose enhancements which is not modeled by Raystation 11B or captured by our PSQA measurements. However, for 5+ field, this effect has previously been shown to be on the order of ~5% of max dose.[2]
- Low Density Inhomogeneity: while RayStation 11B is adequate for the cases evaluated in this study, in patient anatomy with significant low density inhomogeneities (i.e. lung, air pockets), a TPS where parallel B field is explicitly modeled (i.e. RayStation V2025) will be required.[3]

CONCLUSIONS

- The Aurora-RT's unique geometry and MLC can be accurately modeled in Raystation 11B for sIMRT delivery.
- For our 8 mock localized prostate cancer patients, clinically acceptable plans are generated with a simple 5 field IMRT technique with gamma pass rate of ~99.9% at 2%/2mm
- Future Work: Similar validation is to be performed in Raystation V2025, where magnetic field effects are explicitly modeled and to be compared against a validated MC engine [4] (See Abstract ID 23618)

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