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Monte Carlo-Based Patient Specific QA Procedure for Proteus One at UFHPTI

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INTRODUCTION

December 10, 2019, UFHPTI (University of Florida Proton Therapy Institute) started patient treatments using Proteus ONE. Proteus ONE has fast scanning and layer change speed[1]. However, patient specific QA (Quality Assurance) still is a time-consuming activity and occupies plenty of beam time[2]. This paper will explore the potentiality of Monte Carlo-based patient specific QA procedure to replace or assist measurement activity.

AIM

The objective of this work is to commission and validate beam model for Proteus ONE and develop a platform to perform patient specific QA for Proteus ONE based on Monte Carlo software package TOPAS[3].

METHOD

TOPAS beam model was commissioned using system-specific geometry parameters and double Gaussian beam model[4,5] based on in-air lateral dose profiles, integrated depth dose of 33 proton energies ranged from 70 MeV to 227 MeV. The obtained beam model also was validated using various SOBPs and lateral dose distributions in water.

A patient specific QA platform named AutoMCQA was developed and integrated into RayStation treatment planning system script. The obtained TOPAS beam parameters table was used to calculate beam parameters for each energy in TPS treatment plan by AutoMCQA. AutoMCQA also can export and prepare TOPAS input files from RayStation database, and call TOPAS to execute dose calculation. After TOPAS calculation, AutoMCQA will do gamma analysis between TOPAS dose and measurement dose or RayStation dose.

Gamma analysis was performed to prove the stability and accuracy of AutoMCQA for three patient QA plans for head neck, prostate and breast cases, respectively.

RESULTS

The TOPAS beam model was able to calculate proton ranges to within 0.1 mm, and spot sizes to within 2% compared to measured values. Validation of the TOPAS model included gamma analysis of TOPAS-calculated vs. measured planar doses for treatment plans with cubic targets (3x3x3, 5x5x5, 7x7x7 cm3 and Isocenter at 5, 15, 25 cm depth, respectively) in water phantom. As Tab.1 shows, excellent Gamma agreement rates (100% for 3mm/3%, and above 95% for 2mm/2%) for all measurement planes at the proximal, mid, and distal plane depths of these cubic targets. Tab.2 illustrates gamma passing rates of TOPAS calculated doses for three patient plans, including head and neck, prostate and breast cancer, at depths selected for patient plan QA measurements, are above 98.6% (3mm /%3) and 94.6% (2mm/%2) between measurement and TOPAS, good agreement between TOPAS and measurement also are approved.

Fig.1 Dose-depth curves in water for 9 energies

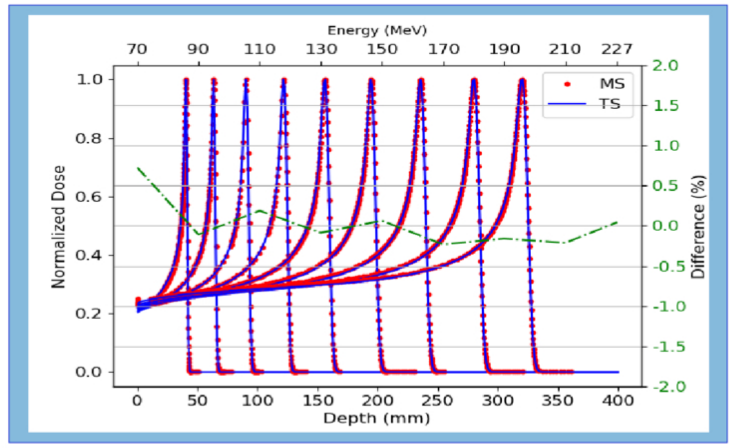
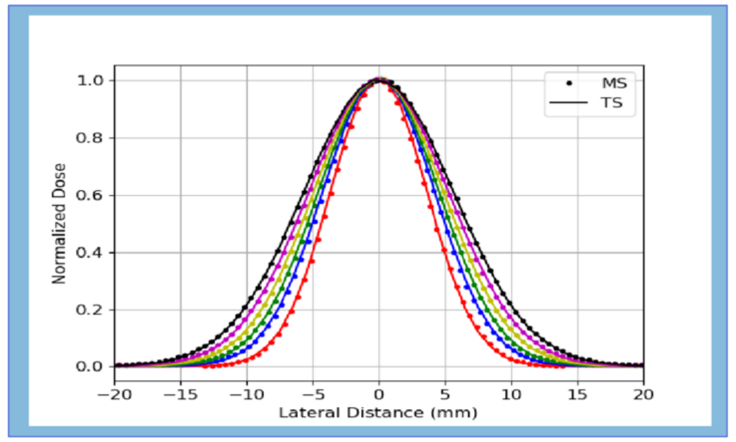


Fig.2 Lateral dose profile of 130 MeV proton beam at positions of -40, -20, -10, 0, 10, 20 cm



Tab.1 Gamma analysis results in uniform target

Plan ID	Target (cm3)	Iso Depth	Measurement Depth (cm)	Gamma(3mm/3%)	Gamma(2mm/2%)
1	3x3x3	5	4,5,6	100,100,100	100,100,97.1
2		15	14,15,16	100,100,100	100,98.3,96.7
3		25	24,25,26	100,100,100	100,97.1,97.3
4	5x5x5	5	3,5,7	100,100,100	100,100,100
5		15	13,15,17	100,100,100	100,96,99.1
6		25	23,25,27	100,100,100	100,97.7,100
7	7x7x7	5	4,5,8	100,100,100	100,99.5,100
8		15	12,15,18	100,100,100	100,98.2,99.4
9		25	22,25,28	100,100,100	99.5,100,100

Tab.2 Gamma analysis results for patient QA plan. MS: measurement, TS: TOPAS, RS: RayStation

Case	Beam Number	MS Depth (cm)	MS-TS		MS-RS		RS-TS	
			3mm/%3	2mm/%2	3mm/%3	2mm/%2	3mm/%3	2mm/%2
H&N	1	4	100	94.6	100	99.3	100	97.7
		6	100	99	99	87.9	100	98.7
	2	4	100	98.1	100	98	100	99.6
		6	100	98.7	100	98	100	99.5
	3	4	98.6	95.1	100	99.3	100	99.2
		6	100	97.4	100	97.4	100	96.1
Breast	1	3	100	100	100	100	100	100
		4.5	100	100	100	99.4	100	99.7
	2	3	100	100	100	100	100	99.8
		4.5	100	100	100	99.9	100	99.7
Prostate	1	18	100	99.1	99.1	90.4	100	98.7
		22	100	98.2	96.4	85.7	100	99.0
	2	18	100	100	100	94.7	100	99.7
		22	100	99	100	93.3	100	99.9

CONCLUSIONS

A highly accurate TOPAS beam model for Proteus ONE has been established and validated. The AutoMCQA software developed to support commissioning of TOPAS greatly facilitated the validation process of our TOPAS beam model, and AutoMCQA also can access RayStation database and transfer treatment plan to TOPAS input file. Considering the calculation time in TOPAS is relatively long (over hours), additional work is planned to reduce the currently excessive long calculation time of TOPAS, for example application of variance reduction techniques, particles scaling and improve server hardware configuration.

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