Implementation of a Novel Cloud-Based Monte Carlo Application for Delivery Performance Monitoring and Secondary Dose Calculation for Tomotherapy: A Multiple-Treatment-Site Study

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AIM

- In this study we evaluated and validated a new cloud-based comprehensive Monte Carlo (MC) application[1] for delivery performance monitoring and dose verification calculations of TomoTherapy® treatment plans for four different treatment sites.
- We then used the results from the MC application to assess the accuracy of the treatment planning system, and delivery accuracy of the treatment machine.

METHOD

- An IRB and Institutional IT approved cloud-based MC code package for TomoTherapy® was used to provide delivery performance monitoring and secondary dose calculations.
- All patient data were anonymized prior to transmission for calculations on the external cloud-based server.
- The MC package was evaluated on four treatment sites: Head and Neck, Brain, Pelvis, and Prostate.
- For each site fifteen plans were evaluated by MC-based dose value histogram (DVH) verification.
- A report generated for the physician and the physicist reviews showing D5, D50, and D95 for each critical structure was created for patient documentation
- Using the post-treatment machine log files and input from the treatment planning system (TPS), a second MC calculation (MCLogQA) utilizing the sinogram acquired by the exit detector after the first fraction of the treatment, was used for delivery performance monitoring.
- MCLogQA was then compared to TPS and MC for agreement, and these comparisons and evaluation are not available on any commercial system.

RESULTS

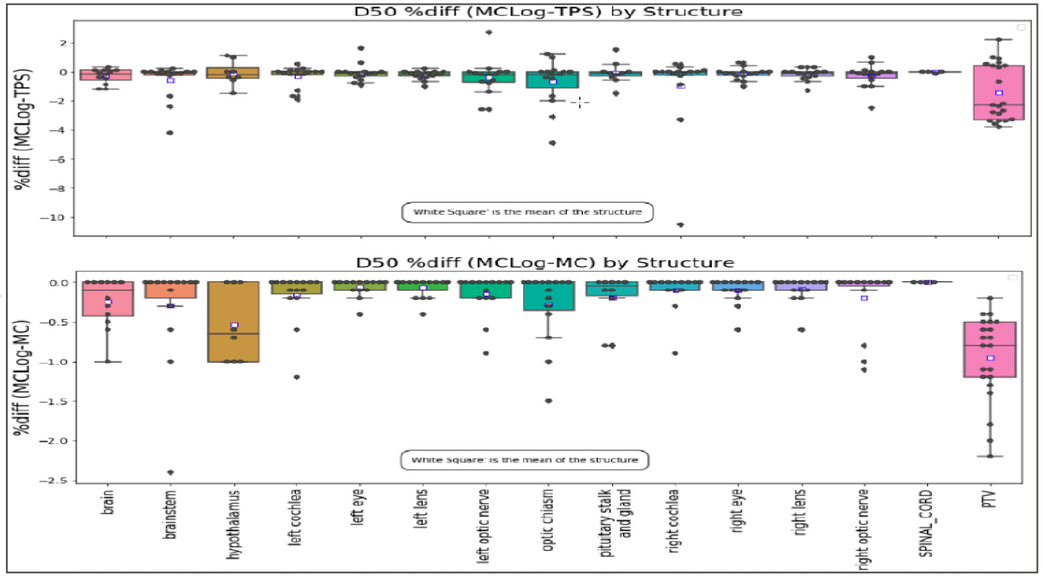
Table 1.

		Head&Neck		Brain		Pelvis		Prostate	
	DVH Metric	OARs	PTV(primary)	OARs	PTV	OARs	PTV	OARs	PTV
%diff (MCLog-TPS)	D5	1.1	2.3	-0.2	1.8	1.9	3	2.2	3.4
	D50	0.1	0.5	-0.4	-1.5	0.7	0.5	1.0	1.7
	D95	-0.1	0.0	-0.4	-3.3	-0.1	-0.4	-0.8	-1.1

Table 2.

		Head&Neck		Brain		Pelvis		Prostate	
	DVH Metric	OARs	PTV(primary)	OARs	PTV	OARs	PTV	OARs	PTV
%diff (MCLog-MC)	D5	0.0	0.4	-0.3	-0.9	0.7	-0.2	0.3	-0.3
	D50	0.0	-0.1	-0.2	-1.0	0.1	-0.4	0.3	0.4
	D95	0.1	0.2	-0.1	-0.9	0.1	-0.3	-0.7	-1.5

Figure 1.



RESULTS

- The MCLogQA results agree well with both TPS and MC, generally within 3% and 1%, respectively, except for low dose regions outside of the field.
- Tables 1 and 2 show the average percentage differences between MCLogQA and TPS, and MCLogQA and MC, respectively. For head and neck treatment plans, only the primary PTV is shown. MCLogQA demonstrates better agreement with MC than TPS.
- The D5, D50, and D95 dose calculations from MC and MCLogQA were all within acceptable agreement to TPS, for all treatment sites. In most of the cases, MCLogQA was either in complete agreement with or predicting slightly less dose compared to MC.
- Figure 1 shows a similar comparison using the average values for D50 for each organ at risk (OAR) among the patient cohort of fifteen, treated for brain malignancies. The white squares indicate the mean values.
- Especially for critical organs such as optic chiasm and hypothalamus, TPS shows disparities that are up to 2% (Fig. 1, top), whereas MCLogQA is in better agreement with MC with <1% difference (Fig. 1, bottom).

CONCLUSIONS

- The studied cloud-based MC tool is a fast, inexpensive, semi-automated alternative to widely practiced clinical standard using phantoms and films for patient-specific QA.
- MC calculation run-time is no more than 10 minutes per plan with an uncertainty parameter set to 0.03, and the cloud-based costs (Amazon) was less than $0.10 per plan.
- The better agreement between MCLogQA and MC was anticipated as both calculations originate from the same model of the beam exiting the linac.
- Comparison with TPS reveals important information about the accuracy of the planning system.
- Our results indicate, comparing D50 for each structure in Figure 1, that our TPS has satisfactory accuracy for the studied treatment plans.

REFERENCES

[1] Chen Q., Westerly D., Fang Z., Sheng K., and Chen Y., "TomoTherapy MLC verification using exit detector data," Med. Phys. **39**, 143–151 (2012).