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Validation of Log File-based Patient 3D Dose Calculation with ArcCHECK 3DVH Reconstruction for Single-isocenter Multiple-target Brain Plans

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ABSTRACT

Purpose: To validate plan-delivery log file-based 3D dose calculations with ArcCHECK (AC) 3DVH reconstruction for single-isocenter multiple-target (SIMT) brain plans

Methods: Twelve SIMT brain plans with a total of 61 targets were selected for the study. All plans were created in Eclipse Treatment Planning System (TPS) (v. 16.1) with non-coplanar VMAT photon beams calculated with AcurosXB (v. 16.1.2) algorithm. They were delivered on a TrueBeam STx linac to produce the corresponding log files (LFs). The patient plan and the corresponding LF were imported to myQA iON system (IBA Dosimetry Gmbh) for 3D dose calculations using a Monte Carlo dose calculation algorithm. The results provided DVH comparison for each target. Patient QA plans were created on and delivered to the ArcCHECK phantom and 3D dose was reconstructed on patient anatomy in the 3DVH software (v. 3.3.1). The mean dose of each target was compared between the LF vs TPS, AC-3DVH vs TPS, and LF vs AC-3DVH.

Results: The mean doses of all 61 targets from the TPS, LF, and AC-3DVH were 28.20 Gy, 27.64 Gy, and 28.95 Gy, respectively. The mean dose percentage difference of the LF vs TPS, AC-3DVH vs TPS, and LF vs AC-3DVH was -1.99%, 2.57%, and -4.55%, respectively. The matched-pairs test values among three comparisons were all less than 0.05, suggesting statistically significant correlation between the calculated and the measured results.

Conclusion: The LF-based calculation and the AC-3DVH reconstructed results showed good agreement with the TPS results within 3.0%. The agreement between the LF-based calculations and the AC-3DVH reconstructed results was within 5.0% and acceptable, considering the uncertainties of the measurement and 3DVH algorithm. These results validated that the LF-based method has sufficient accuracy for 3D dose verification of SIMT brain plans.

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INTRODUCTION

Pre-treatment dose verification of single-isocenter multiple-target (SIMT) SRS plans is challenging due to multiple off-isocenter targets. Conventional 2D methods cannot measure all the targets simultaneously. 3D dose verification is ideal for SIMT plans but extremely difficult due to limitations on current measurement devices.

Plan delivery log-file (LF) analysis has been proposed to be an effective and practical approach in verifying 3D dose of SIMT plans with non-coplanar VMAT beams. But its accuracy and error detection sensitivity requires thorough investigation and is subject to validation by the conventional phantom-based measurement.

This study cross-checked and validated the plan-delivery log file-based 3D dose results with the ArcCHECK 3DVH reconstruction for SIMT brain plans.

METHODS AND MATERIALS

Twelve SIMT brain plans with a total of 61 targets were selected for the study. The volumes of the targets ranged from 0.05 cc to 72.0 cc. The minimum and maximum distances between the target and the isocenter were 0.56 cm and 7.8 cm, respectively.

All plans were created in Eclipse Treatment Planning System (TPS) (v. 16.1) with non-coplanar VMAT photon beams calculated with AcurosXB (v. 16.1.2) algorithm. They were delivered on a TrueBeam STx linac to produce the corresponding log files (LFs).

Each patient's plan and the corresponding LF were imported to myQA iON system (IBA Dosimetry Gmbh) for 3D dose calculations using a Monte Carlo dose calculation algorithm. The results included an independent 2nd dose calculation and a LF-based 3D dose reconstruction. These results provided 3D dose and DVH comparison for each target, as well as 3D gamma analysis for the plan.

Patient QA plans were created on ArcCHECK (AC) phantom and were delivered to the AC phantom. The 3D dose was then reconstructed on the patient anatomy in the 3DVH software (v. 3.3.1) based on the AC measurement results.

The mean dose of each target was compared between the that of the LF vs TPS, AC-3DVH vs TPS, and LF vs AC-3DVH.

RESULTS

The mean doses of all 61 targets from the TPS, LF, and AC-3DVH were 28.20 Gy, 27.64 Gy, and 28.95 Gy. The mean dose percentage difference of the LF vs TPS, AC-3DVH vs TPS, and LF vs AC-3DVH was -1.99%, 2.57%, and -4.55%, respectively. Figure 1.

The matched-pairs test values among 3 comparisons were all much less than 0.05, suggesting statistically significant correlation between the calculated and the measured results.

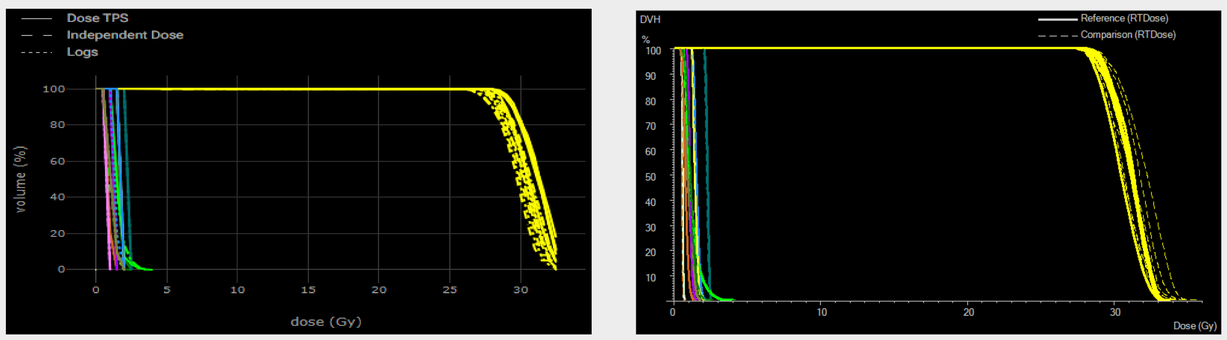
RESULTS

Figure 1. The graphs below show the dose percentage difference of the LF vs TPS, AC-3DVH vs TPS, LF vs AC-3DVH, and 2nd Cal vs TPS for all 61 targets, where the 2nd Cal was the secondary independent dose calculation by myQA iON using the same Monte Carlo algorithm as for the LF 3D dose reconstruction.

Table 1. An example of a 6-target brain case. The prescribed dose was 5.5 Gy x 5. Shown in the table are the target volume (Vol), distance to iso (Dist.), mean dose (Gy) from the TPS, AC-3DVH, LF, and 2nd dose calculation (2nd Cal).

Target	Vol (cc)	Dist. (cm)	TPS (Gy)	3DVH (Gy)	3DVH vs TPS	LF (Gy)	LF vs TPS	2nd Cal (Gy)	2nd cal vs TPS
1	2.114	4.89	30.98	32.02	**3.37%**	30.39	**-1.90%**	30.31	**-2.16%**
2	2.013	6.07	31.01	31.59	**1.87%**	30.27	**-2.39%**	30.20	**-2.61%**
3	1.911	7.11	31.00	30.56	**-1.44%**	29.62	**-4.45%**	29.57	**-4.61%**
4	1.248	6.93	31.01	30.95	**-0.19%**	29.87	**-3.68%**	29.85	**-3.74%**
5	13.341	5.07	30.4	30.54	**0.47%**	30.06	**-1.12%**	30.02	**-1.25%**
6	1.329	7.2	31.11	30.84	**-0.87%**	29.89	**-3.92%**	29.78	**-4.28%**

Figure 2. Overlay of the DVH of the TPS, 2nd independent dose, and log-file dose from myQA iON (Left); and of the TPS (Reference) and the AC-3DVH (Comparison) (Right) from ArcCHECK measurement for this 6-target brain case.



CONCLUSIONS

The LF-based calculation and the AC-3DVH reconstructed results (mean dose percentage difference) agreed with the TPS results within 3.0%. The agreement between the LF-based calculations and the AC-3DVH reconstructed results was within 5.0% and acceptable, considering the uncertainties of the measurement and 3DVH algorithm. These results validated that the LF-based method has sufficient accuracy for 3D dose verification of SIMT brain plans.

DISCUSSION

The ArcCHECK system can provide 3D dose analysis but have limitations for SIMT plans. Its spatial resolution is 1 cm and is coarse for small targets. When an effective beamlet aperture is < 4 x 4 cm^2, it cannot calculate the gantry angle accurately as only limited number of diodes are in the entrance and exit apertures. This affects the accuracy of the AC results.

REFERENCES

1. Feygelman et al., Cross-validation of two commercial methods for volumetric high-resolution dose reconstruction on a phantom for non-coplanar VMAT beams. Radiotherapy and Oncology, 2014.
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