Evaluation of 3D pre-treatment verification for volumetric modulated arc therapy plan in head region

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Abstract. The development of pre-treatment QA tools contributes to the three dimension (3D) dose verification using the calculation software with the measured planar dose distribution. This research is aimed to evaluate the Sun Nuclear 3DVH software with Thermo luminescence dosimeter (TLD) measurement. The two VMAT patient plans (2.5 arcs) of 6 MV photons with different PTV locations were transferred to the Rando phantom images. The PTV of the first plan located in homogeneous area and vice versa in the second plan. For treatment planning process, the Rando phantom images were employed in optimization and calculation with the PTV, brain stem, lens and TLD position contouring. The verification plans were created, transferred to the ArcCHECK for measurement and calculated the 3D dose using 3DVH software. The range of the percent dose differences in both PTV and organ at risk (OAR) between TLD and 3DVH software of the first and the second plans were -2.09 to 3.87% and -1.39 to 6.88%, respectively. The mean percent dose differences for the PTV were 1.62% and 3.93% for the first and the second plans, respectively. In conclusion**,** the 3DVH software results show good agreement with TLD when the tumor located in the homogeneous area.

1. Introduction

VMAT is the advance technique that developed from the intensity modulated radiation therapy (IMRT) technique. The VMAT parameters allow for variation of the MLC movement, dose rate and gantry rotation speed. These affect the plan to be more complicated. Therefore, the pre-treatment verification is very important to make sure that the modulated dose is accurate [1].

The pre-treatment verification by dose measurement is used to evaluate the treatment planning. Traditional of devices for doing this process are point dosimetry, planar dose distribution and 3D dose comparison. Previously, the reporting of verification treatment plan illustrated a planar dose distribution in criteria of 95% gamma pass ($\gamma \leq 1$) by using a 2D planar dose distribution. But it was found that the limitation in dose distribution did not relate to the patient dose [2].

Currently, the software can generate the dose measurement to 3D as DVHs to compare with treatment planning system (TPS) such as the 3DVH software. The 3DVH software is commercially available software program and used with the ArcCHECK device (both Sun Nuclear Corp., Melbourne, Florida, USA). The 3DVH software needs patient DICOM files (RT plan, RT dose, RT structures, and CT images) from TPS. The treatment plan is verified by creating a planned dose perturbation (PDP) file from errors in comparison between patient RT dose and ArcCHECK RT dose. The errors are convolved

in ArcCHECK measurement data. The evaluation base on estimate dose to patient by overlay the resultant PDP beams on the patient CT images and show clinical impact using a DVHs analysis tool [3].

Since 2013, our previous studies were the evaluation of 3D commercial QA software in patient treatment plans. In some cases, we observed that dose in PTV from 3DVH software were lower than TPS [4]. These issues shall be addressed in this study. The purpose of this work is to evaluate the volume dose from 3DVH software comparing with the TLD measurement in Alderson Rando phantom of VMAT technique.

2. Material and methods

The TLD-100 were calibrated and used for measurement in this study. The two VMAT plans of Rando phantom in the head region were selected and verified by the 3DVH software. The studies were performed by volume dose comparison between measurement in TLD and 3DVH software for pre-treatment verification.

2.1. TLD characteristics

The TLD-100 (LiF:Mg, Ti) with 3.2 x 3.2 x 0.38 mm^3 were employed in this study. The 120 TLD chips were calibrated with 100 cGy of 6 MV photon beam. The 8 TLD chips were selected as a standard and 82 TLD chips were used for measurement in this study.

The dose response of TLD were investigated in 6 MV photon beam. The doses were varied from 0 to 300 cGy (0, 2, 5, 10, 20, 50, 100, 150, 200, 250 and 300 cGy). The parameters of measurement were 400 MU/min dose rate, 12x12 cm^2 field size and 100 cm source to detector distance. The dose linearity was evaluated by regression coefficients. Also, the dose minimum detectability of TLD was reported.

2.2. Treatment planning system

The Alderson Rando phantom was scanned by CT-scanner (LightSpeed RT GE Medical system, Waukesha, WI, USA) with 2.5 mm slice thickness in the head region. The two patient plans of VMAT treatment technique (2.5 arcs) in the head region of our previous study were selected for investigation [5]. The head Rando phantom images were registered with the two patient plans in the PTV, brain stem, lens and TLD position contouring. The head Rando phantom images were optimized and calculated in the Eclipse treatment planning software (Version 11.0.31, Varian Medical System, Palo Alto, CF, USA) by VMAT technique with the 6 MV photon beam, 2.5 arcs rotation and 54 Gy prescription dose in PTV (200 cGy dose per fraction).

2.3. Pre-treatment verification

2.3.1. TLD measurement. The two VMAT plans were transferred to the Varian ClinaciX linear accelerator (Varian Medical systems, Palo Alto, CA, USA) for measurement. The TLD ships were inserted into the Alderson Rando phantom in location of PTV, brain stem and lens. The Alderson Rando phantom was set on treatment couch with laser alignment and irradiated with the parameter from TPS. Also, the standard TLD chips were exposed with 105 MU at 100 cm source to detector distance and 12x12 cm^2 field size for daily output correction. The TLD ships were read by Harshaw TLD 5500 dosimeter reader and WinREMS software program. The mean organs dose in PTV, brain stem and lens were reported.

2.3.2. Arc Check measurement and 3DVH software calculation. The ArcCHECK phantom was placed on treatment couch at 86.65 cm source to detector distance. The calibrated dose of detector were performed before measurement with parameters; 6 MV photon beam, 10x10 cm^2 field size and 200 cGy as a 163 MU dose delivered. The two verification VMAT plans of head region were created in ArcCHECK phantom and transferred to measurement.

For 3DVH software, the Alderson Rando phantom DICOM flies (RT plan, RT dose, RT structures, and CT images) were imported. The DVHs and 3D gamma passed were generated by 3DVH software.

3. Results

3.1. TLD characteristics

The results of TLD dose linearity of 6 MV photon beams over 0 to 300 cGy delivered dose are shown in figure 1. The graphs plotted between collected TLD signal and delivered dose for 6 photon beams are shown with regression coefficients of 0.9994. The dose minimum detectability of TLD was 0.01 cGy.

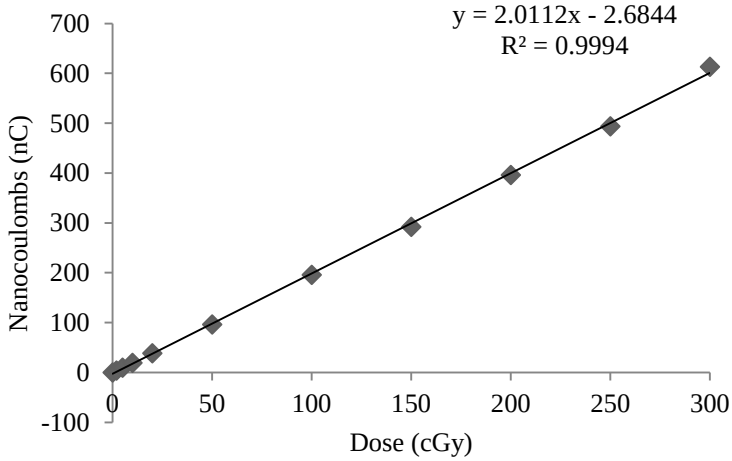

Figure 1. TLD dose response of 6 MV photon beam as function of delivered dose from 0 to 300 cGy.

3.2. Pre-treatment verification

Table 1-2 illustrate the percent dose differences between TLD and 3DVH software calculation, case No.1 and case No.2 were ranged from -2.09 to 3.87% and from -1.39 to 6.88%, respectively. The mean percent dose differences in PTV of case No.1 showed good agreement between TLD and 3DVH software. For case No.2, the mean dose difference in PTV was 3.93%.

Table 3-4 describe the percent dose differences from TLD in OARs which showed the large variation. The percent gamma passed with 3%/3mm criteria of 3DVH was 99.5% and 95.5% for case No. 1 and case No. 2, respectively.

Table 1. The percent dose differences between TLD and 3DVH software calculation in PTV of case No.1.

Organs	TLD No.	TLD ± SD (cGy)	3DVH (cGy)	%Dose diff.
PTV	1	206.14±2.14	201.30	2.35
	2	205.65±2.32	201.70	1.92
	3	205.90±4.85	205.10	0.39
	4	213.35±43.08	206.30	3.30
	5	204.92±5.80	209.20	-2.09

	6	214.55±26.00	207.20	3.43
	7	213.57±34.45	205.30	3.87
	8	205.52±3.29	206.40	-0.43
	Mean	208.70	205.31	1.62

Table 2. The percent dose differences between TLD and 3DVH software calculation in PTV of case No.2.

Organs	TLD No.	TLD ± SD (cGy)	3DVH (cGy)	%Dose diff.
PTV	1	208.18±2.09	198.80	4.51
	2	207.35±6.26	194.90	6.00
	3	204.65±3.62	198.60	2.96
	4	208.34±36.94	194.00	6.88
	5	205.10±4.82	197.10	3.90
	6	213.32±27.57	203.00	4.84
	7	175.27±28.01	177.70	-1.39
	8	200.11±2.35	196.00	2.05
	9	211.02±8.33	201.10	4.70
	Mean	203.70	195.69	3.93

Table 3. The percent dose differences between TLD and 3DVH software calculation in brain stem and lens of case No.1.

Organs	TLD No.	TLD ± SD (cGy)	3DVH (cGy)	%Dose diff.
Brain stem	9	2.57±1.69	5.40	-110.12
	10	5.79±3.36	5.80	-0.17
Lt. lens	11	2.79±1.07	3.70	-32.62
Rt. lens	12	3.05±0.14	4.30	-40.98

Table 4. The percent dose differences between TLD and 3DVH software calculation in brain stem and lens of case No.2

Organs	TLD No.	TLD ± SD (cGy)	3DVH (cGy)	%Dose diff.
Brain stem	10	35.80±20.84	33.70	5.87
Lt. lens	11	34.36±14.47	17.30	49.65
Rt. lens	12	36.55± 1.17	22.70	37.89

4. Discussion

The aim of this study is to evaluate the 3DVH software accurately predict the dose by direct comparing absolute dose to TLD measurement in Alderson Rando phantom. The characteristics of TLD were determined before making the measurement. The TLD signal increase linearly with the dose delivered with the regression coefficients of 0.9994 for 6 MV photon beams and 0.01 cGy dose detectability. The TLD is suitable for measurement in VMAT technique with 200 cGy dose per fraction.

For pre-treatment verification, the results show good agreement between measurement and calculation in PTV of case No.1. The result of case No. 2 shows lower dose about 3.93% from TLD measurement. These agree with our previous study that reported lower dose in 3DVH software of patient plans for tumor located in the inhomogeneity area [4]. The 3DVH software uses the dose error between measured in Arc CHECK and calculated from TPS with applied the PDP algorithm to obtain the 3D dose. The inhomogeneity is included in the dose error, special calculation is not taken. The size and shape of tumor and organ at risks also influence the dose report. For brain stem and lens, the result shows large variation. Some part of OARs is in the PTV resulted in high dose gradient. Also, the OARs

have a small volume and locate in low dose region. This can effect to the response of TLD and may cause to misinterpretation.

By comparison of previous works, Olch J evaluated the accuracy of 3DVH software estimates of dose to virtual ion chamber and film that indicated the 3DVH system may accurately substitute for patient-specific IMRT QA [5]. However in VMAT technique, our results illustrating the 3DVH QA software is suitable to calculate in 3D pre-treatment verification as well.

5. Conclusions

The 3DVH software results show good agreement with TLD when tumor is located in the homogeneities area. The 3DVH software is suitable for reporting of dose differences in pre-treatment verification in VMAT technique of head region.

References

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