Evaluation of doses delivered by SBRT to the lung of an anthropomorphic thorax phantom

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Introduction

The RTOG 0236 protocol evaluates a stereotactic body radiation therapy (SBRT) technique in treatment of patients with medically inoperable stage I/II non small cell lung cancer. The schema for this treatment is 20 Gy per fraction for 3 fractions over 1½-2 weeks, for a total of 60 Gy. The objective of the study is to determine if radiotherapy involving this type of technique achieves acceptable local control and acceptable treatment-related toxicity in patients with medically inoperable early stage non-small cell lung cancer.

Institutions must be credentialed by the RTOG before enrolling patients on this study. This process includes the following steps: complete and submit the Facility Questionnaire to the Image-Guided Therapy QA Center (ITC); obtain IRB approval for this protocol; submit documentation about immobilization, localization and respiratory motion control system to RTOG headquarters; demonstrate the capability to submit plans from the institution's treatment planning system (TPS) to the ITC; successfully complete a phantom irradiation dosimetry test and perform a "dry run" test.

For the phantom step the RPC designed an anthropomorphic thorax phantom. An evaluation of doses delivered through this technique is presented in this poster.

Methods and materials

The thorax phantom is a water fillable plastic shell that simulates the human thorax.

It has structures that represent lungs, the spinal cord and the heart not only in dimension but also in values of tissue density for imaging and treatment purposes.(Figure 1)

Fig 1: Thorax phantom:plastic shell and internal structures

Materials/Methods continued

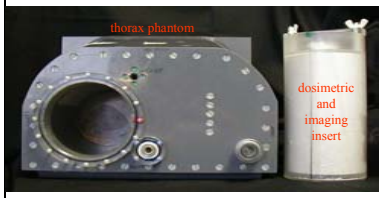

Fig 2: Thorax phantom and insert

Part of the left lung is a removable insert that includes a centrally-located oval tumor as well as dosimetric systems (Figure 2). The dosimeters are placed to analyze the dose distribution and are:

2 TLD inside GTV

1 TLD inside heart

1 TLD inside spinal cord

3 sheets of GafChromic® film in axial, sagittal and coronal planes

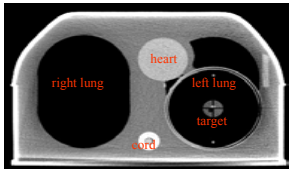

Fig 3: CT of thorax phantom

The TLDs located inside the GTV are near the center of the tumor and are used for absolute dose determination.

The institution was instructed to image the phantom and plan a treatment without applying correction for tissue heterogeneity, following constraints that matched the indications for the study. The institution was asked to deliver the treatment to the phantom as if to a patient.

The institution was asked to submit the isodose distribution for the a plan calculated without applying correction for tissue heterogeneity and distribution for the same plan with this correction. The phantom, with the dosimetry systems intact, was then returned to the RPC.

The information obtained from the dosimetry system included in the phantom was compared to the isodose distribution reported by the TPS. Profiles on three perpendicular axes were taken from the films and the dose was normalized to the TLD dose.

Results

Table 1 shows a list of the TPS used by the first group of institutions.

Table 1: TPS used for dose calculations

Name	TPS	Dose Calc. Algorithm
Inst. 1	Precise Plan v2.01	Scatter integration Clarkson Type
Inst. 2*	Brain Lab V5.21	Pencil Beam
Inst. 3*	Brain Lab	Clarkson & Pencil Beam
Inst. 4	Pinnacle V6.2b	CC Convolution
Inst. 5	Pinnacle V6.2b	CC Convolution
Inst. 6	Render Plan	Changes in primary attenuation only
Inst. 7	Precise Plan v2.01	Area Integ. Clarkson (effective path length)

Table 2 shows details of the results. Note that for Institutions 2 and 3 there was no displacement analysis. Because these TPSs were not capable of exporting data in the required format, it was not possible to conduct a detailed electronic analysis of the data.

Table 2: Dose and displacement results

Name	Correction off				
	TLD / Inst Dose		Displacement (mm)		
	PTV sup	PTV inf	Inf / Sup	Lt / Rt	Post/Ant
Inst. 1	1.180	1.179	0 / 2	1 / 6	-1 / 4
Inst. 2*	1.159	1.134			
Inst. 3*	1.201	1.199			
Inst. 4	1.114	1.111	2 / 2	2 / 2	3 / 4
Inst. 5	1.143	1.126	-1 / 0	-3 / 2	-2 / 5
Inst. 6	1.125	1.095	1 / -1	-6 / 3	8 / -3
Inst. 7	1.171	1.171	-2 / -3	0 / 2	1 / 2

Name	Correction on				
	TLD / Inst Dose		Displacement (mm)		
	PTV sup	PTV inf	Inf / Sup	Lt / Rt	Post/Ant
Inst. 1	1.011	1.008	2 / 0	4 / 2	5 / 2
Inst. 2*	0.946	0.934			
Inst. 3*	0.976	0.974			
Inst. 4	0.950	0.955	2 / 3	3 / 1	5 / 3
Inst. 5	0.993	0.979	0 / 0	- 2 / 0	-2 / 5
Inst. 6	0.938	0.912	2 / -3	-3 / 0	2 / 2
Inst. 7	0.972	0.962	1 / -5	4 / -2	4 / -5

The results of the first seven institutions were used to analyze parameters of the irradiation and set criteria for the evaluation of the test.

Results continued

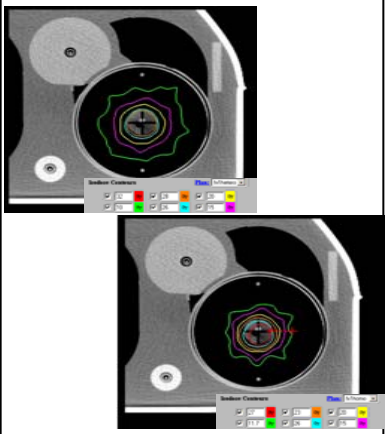

Fig 4: Isodose distribution from Remote review tool from ITC. The distance between red crosses on the homogeneous case is 2cm.

Discussion

The average ratio of TLD dose and TPS calculated dose to TLD was 0.97 ± 3% for the plan with correction on and was 1.15 ± 3% for the plan with correction off. An analysis of the displacement between dose distributions obtained from the films and from the TPS was done in the region around the target. The maximum displacement found was 5mm. An example of dose profile in one particular combination of plane and direction is shown in Figure 5.

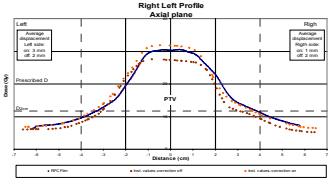

Fig 5: Dose profile comparison on the transverse axis. The displacement between film values and TPS values is presented for both situations (correction on and off).

Discussion continued

Parameters such as the calibration protocol and reference medium used for the determination of the output as well as the previous TLD history were taken into account to analyze the dose discrepancies found. The most important cause of discrepancy was the algorithm used by the TPS in the determination of dose. Another parameter that affected the results was the table of tissue densities used to convert CT numbers to densities.

The following criteria were established for the approval of the phantom test.

Based on results from the dose distribution when the correction for tissue heterogeneity is applied:

- RPC/Inst dose to PTVs: 0.92-1.02
- Distance to agreement in high gradient region near OAR: ≤ 5 mm

Based on results from the dose distribution when the correction for tissue heterogeneity is not applied:

- At least 95% of the PTV received 20Gy.
- At least 99% of the PTV received 18Gy.
- Dose at 2cm radial distance from the PTV does not exceed 11.7Gy

Conclusion

Criteria for the evaluation of this test were set based on these first results. A range of ± 5% around 0.97 was established for discrepancy of dose at the center of the target and a maximum of 5mm was established for the displacement between the TPS dose distribution and film profile near the target. Both criteria are for values based on calculations performed with tissue heterogeneity correction applied. The dose discrepancies found in these preliminary results are consistent with the values obtained by Gary Fisher (AAPM 2004) using the same phantom.

These criteria will be re-evaluated after data from 20 institutions have been analyzed.

References

[3] G. Fisher, G. , Followill, D. S. ,Ibbott, G. The accuracy of 3-D inhomogeneity photon algorithms in commercial treatment planning system using a heterogeneous lung phantom.

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