Evaluation of IMRT for Institutions Participating in NCI Sponsored Clinical Trials

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Purpose

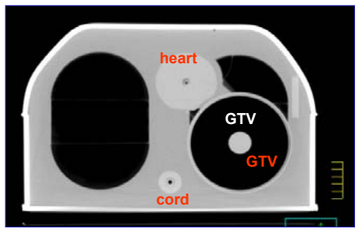
Institutions must be credentialed to participate in NCI protocols that allow or require IMRT. The RPC has developed a family of phantoms that are used as a credentialing tool to evaluate the IMRT treatment delivery process of these institutions.

Materials/Methods

The phantoms consist of a plastic outer shell and internal structures to represent anatomy. A thorax phantom contains lung-equivalent regions, one of which contains a GTV. A pelvic phantom contains structures representing the prostate, rectum, and bladder. A third IMRT phantom mimics the head and neck region and contains structures representing a planning target volume (PTV) close to an organ at risk (OAR), simulating an orophanryngeal tumor and the spinal cord. The phantom contains a secondary PTV that simulates peripheral nodes. In each phantom, thermoluminescence dosimeters (TLDs) were embedded in each target volume and several of the OARs, and GafChromic® film was inserted in two or three planes through the PTVs.

Institutions were instructed to fill the shell with water on-site, image the phantom, plan a treatment according to RPC guidelines and irradiate the phantom. The institutions were also asked to follow the QA procedures that would be done for a patient. Upon completion the institutions returned the phantom to the RPC. The TLD and film were evaluated by the RPC.

Thorax Phantom



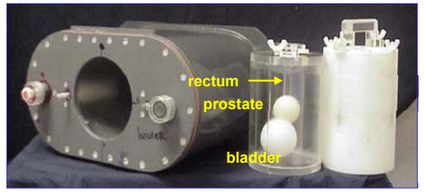
The thorax phantom consists of the following:

- GTV containing 2 TLD
- Heart containing 1 TLD
- Cord containing 1 TLD
- GafChromic® film in axial, sagittal and coronal planes

The thorax phantom is currently being used to evaluate a stereotactic body irradiation therapy procedure. A study to validate its use for measuring IMRT treatments is underway.

Materials/Methods continued

Pelvic Phantom

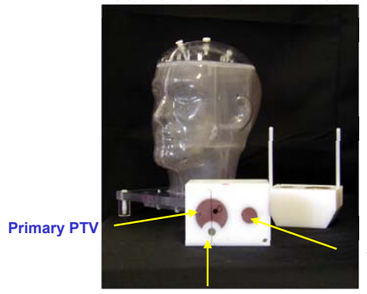


The pelvic phantom consists of the following:

- Prostate housing 2 TLD
- Bladder
- Rectum
- 2 Femurs each containing 1 TLD
- GafChromic® film in sagittal and coronal planes

The institution is instructed to deliver 18 Gy in 10 fractions to at least 98% of the PTV. A maximum dose of 19.3 Gy may be given to < 2% of the PTV. No part of these normal organs shall receive more than 20 Gy

Head and Neck Phantom



The head and neck phantom consists of the following:

- Primary PTV containing 4 TLD
- Secondary PTV containing 2 TLD
- Organ at risk containing 2 TLD
- GafChromic® film in axial and sagittal planes

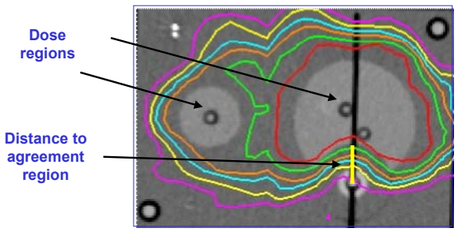
The institution is instructed to give 6.6 Gy to at least 95% of the primary PTV. 5.4 Gy should be given to at least 95% of the secondary PTV. The organ at risk is limited to less than 4.5 Gy.

Materials/Methods continued

Criteria for credentialing:

RPC/Inst dose in PTVs: 0.93-1.07

Distance to agreement in high gradient region near OAR: ≤ 4 mm



This is an example of how the criteria are applied in the head and neck phantom.

Results

Pelvic Phantom results

13 irradiations were analyzed

11 irradiations met the criteria

2 irradiations failed to meet the criteria

13 institutions are represented

Both of the institutions that failed did not meet the distance to agreement criteria that is applied to the film results.

Head and Neck Phantom results

109 irradiations were analyzed

75 irradiations passed the criteria

(20 institutions irradiated multiple times)

34 irradiations failed to meet the criteria

85 institutions are represented

19 failed by TLD results only

5 failed by film results only

10 failed by both film and TLD results

Only 66% of institutions irradiating the head and neck phantom passed the criteria on the first irradiation.

Results continued

Head and neck phantom results continued

The following table summarizes the TLD and film results

	1° PTV	2° PTV	OAR	Displ.(mm)
mean	1.01	1.00	1.08	-0.8
std dev	0.053	0.051	0.25	3.5
count	274	137	137	109
range	0.78-1.13	0.81-1.22	0.42-2.24	*-15 - 10*

The following tables show an analysis of the results, comparing accelerator manufacturer, treatment planning system, IMRT technique and intensity modulation device. The criteria for which most data are available are highlighted in yellow.

Linear Accelerator Manufacturer	Fails	Attempts	Criteria Failed		
			TLD only	Film only	TLD and Film
BrainLab	0	1	0	0	0
Elekta	3	7	2	1	0
Siemens	6	19	3	0	3
TomoTherapy	1	3	1	0	0
Varian	24	79	13	4	7
total	34	109	19	5	10

Treatment planning system	Fails	Attempts	Criteria Failed		
			TLD only	Film only	TLD and Film
BrainScan	0	1	0	0	0
Cadplan	1	2	1	0	0
CMS XiO	1	7	0	0	1
Corvus	7	24	6	0	1
Eclipse	4	20	1	2	1
Helax	0	2	0	0	0
Pinnacle	17	44	9	3	5
Radionics XKnife	0	1	0	0	0
Theraplan Plus	2	2	0	0	2
TomoTherapy	1	3	1	0	0
Inst. developed TPS	1	3	1	0	0
total	34	109	19	5	10

IMRT technique	Fails	Attempts	Criteria Failed		
			TLD only	Film only	TLD and Film
Dynamic MLC	4	20	2	1	1
IMAT	4	8	3	0	1
Segmental	25	78	13	4	8
TomoTherapy	1	3	1	0	0
total	34	109	19	5	10

Intensity modulation device	Fails	Attempts	Criteria Failed		
			TLD only	Film only	TLD and Film
Binary	4	9	3	0	1
MLC	30	100	16	5	9
total	34	109	19	5	10

Results continued

Head and neck phantom results continued

Explanations for Failures

The following are known explanations for some of the failures:

- incorrect output factors in TPS
- incorrect PDD in TPS
- inadequacies in beam modeling at leaf ends (Cadman, et al; PMB 2002)
- not adjusting MU to account for dose differences measured with ion chamber
- errors in couch indexing with Peacock system
- setup errors

Conclusion

Failures occurred in irradiations delivered by a variety of models of linear accelerator and planned with several treatment planning systems (TPS). Somewhat consistent behavior was seen among the TPSs, although no trends were apparent among the delivery devices. The phantom was valuable for evaluating IMRT treatments at institutions preparing to participate in advanced technology clinical trials.

The phantom is valuable for evaluating IMRT for clinical trials

QA of IMRT is important!

References

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[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. AAPM 46th annual meeting, Pittsburgh 2004

[4] Cadman, P., Bassalow, R., Sidhu, N.P.S., Ibbott, G., Nelson, A., Dosimetric considerations for validation of a sequential IMRT process with a commercial treatment planning system. *Physics in Medicine and Biology* Vol. 47, 3001-3010, 2002.

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