IMRT Head and Neck Phantom Irradiations: Correlation of Results with Institution Size

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Purpose:

To analyze the results from 150 irradiations of an IMRT H&N phantom.

Methods and Materials:

A mailable anthropomorphic IMRT head and neck phantom was irradiated 150 times by 117 institutions. Some institutions irradiated multiple times. Institutions imaged the phantom, planned an IMRT treatment, performed their routine IMRT QA checks, and irradiated the phantom according to their plan. The phantom contained imageable structures representing a planning target volume (PTV) close to an organ at risk (OAR), simulating an oropharyngeal tumor and the spinal cord. The phantom also contained a secondary PTV that simulated peripheral nodes. TLDs were placed in each structure and a set of orthogonal radiochromic films intersected in the primary PTV. The following criteria were used to evaluate the measurements: TLD/institution dose – ± 7%; distance-to-agreement in the high dose gradient region near the OAR – ≤ 4 mm. The failure rate of institutions that housed 3 or fewer megavoltage therapy machines was compared to that of larger institutions. The results for all institutions was also analyzed by looking at the failure rates for types of accelerator, treatment planning systems, IMRT technique and the number of physicists per machine at the institution.

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

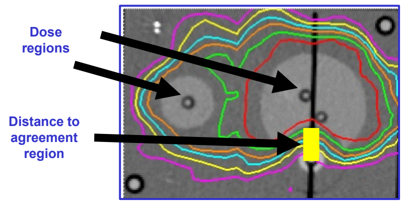
The institution is instructed to give 6.6 Gy to at least 95% of the primary PTV. 5.4 Gy should be given to at least 95% of the secondary PTV. The organ at risk is limited to less than 4.5 Gy.

Methods and Materials continued:

Criteria for credentialing:

RPC/Inst dose in PTVs: 0.93-1.07

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



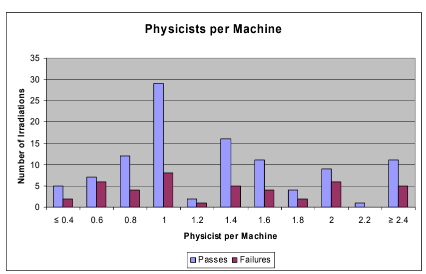
This is an example of how the criteria are applied in the head and neck phantom.

Results:

43 irradiations failed to meet one or more of the criteria. 26 of the failures were dose discrepancies measured with TLD, 5 were dose distribution discrepancies measured with radiochromic film and 12 were disagreements in both TLD and film measurements. There was a 33% discrepancy rate in first-time irradiations at the institutions with 3 or fewer machines and a 29% rate at the larger institutions. All of the institutions that failed multiple times were smaller institutions.

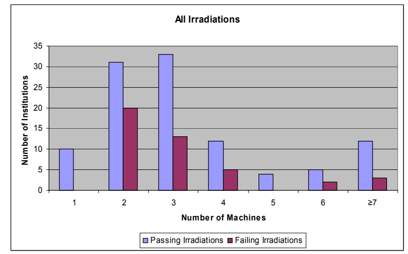
83 institutions with 3 or fewer machines irradiated the phantom. 27 of the first time irradiations were failures. There were 6 repeat failures. 34 institutions with more than 3 machines irradiated the phantom. 10 of the first time irradiations were failures. There were no subsequent failures in this group.

The following graph shows the passing and failing irradiations separated by the number of physicists per machine. There was a 32% failure rate for institutions employing less than 1 physicist per machine and a 27% failure rate for institutions employing 1 or more physicists per machine.

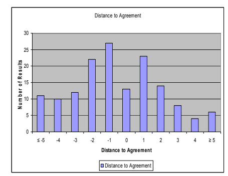


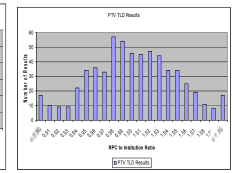
Results continued:

The following graph shows the passing and failing irradiations sorted by the number of megavoltage therapy machines at the institution.



The following graphs show the spread of the results from the TLD in the PTVs and the spread of the DTA results.





The following tables detail results sorted by linear accelerator manufacturer, treatment planning system and IMRT technique.

Treatment planning system	Failures	Attempts	Criteria Failed		
			TLD only	Film only	TLD and Film
BrainScan	0	4	0	0	0
Cadplan	1	2	1	0	0
CMS XiO	3	13	1	0	2
Corvus	7	26	6	0	1
Eclipse	5	30	2	2	1
Helax	0	2	0	0	0
Pinnacle	23	63	14	3	6
Radionics XKnife	0	1	0	0	0
Theraplan Plus	2	2	0	0	2
TomoTherapy	1	3	1	0	0
Inst. developed TPS	1	4	1	0	0
total	43	150	26	5	12

Linear Accelerator Manufacturer	Failures	Attempts	Criteria Failed		
			TLD only	Film only	TLD and Film
BrainLab	0	1	0	0	0
Elekta	4	9	3	1	0
Siemens	8	27	4	0	4
TomoTherapy	1	3	1	0	0
Varian	30	110	18	4	8
total	43	150	26	5	12

Results continued:

IMRT technique	Failures	Attempts	Criteria Failed		
			TLD only	Film only	TLD and Film
Dynamic MLC	5	29	3	1	1
IMAT	4	9	3	0	1
Segmental	33	109	19	4	10
TomoTherapy	1	3	1	0	0
total	43	150	26	5	12

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

Conclusions:

Institutions of all sizes are capable of making mistakes in IMRT treatments. Sufficient physics coverage is an important aspect of IMRT quality assurance.

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 technique. The phantom was valuable for evaluating IMRT treatments at institutions preparing to participate in advanced technology clinical trials.

References

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.

Molineu, A., Followill, D.S., Balter, P., Hanson, W.F., Gillin M.T., Huq, M.S., Eisbruch, A.E. and Ibbott, G.S., Design and Implementation of an Anthropomorphic Quality Assurance Phantom for Intensity Modulated Radiation Therapy for the Radiation Therapy Oncology Group, in press by Red Journal.

Support:

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