Has IMRT delivery improved in the last 5 years?

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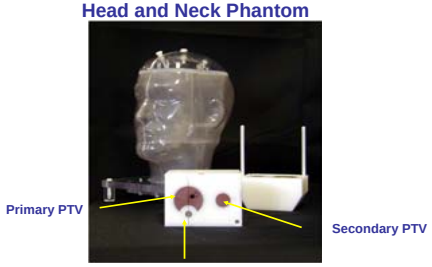
Purpose:

To determine whether institutions that participate in clinical trials are delivering IMRT more accurately today than they were when the RPC auditing program began in 2001.

Methods and Materials:

A mailable anthropomorphic IMRT head and neck phantom was irradiated 572 times by 416 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 (axial and sagittal planes) 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 current failure rate was compared to the failure rate in 2005 to determine if IMRT delivery has improved over the past few years. The results for all institutions were also analyzed by looking for correlations between the failure rates and type of accelerator, treatment planning systems, and IMRT technique 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

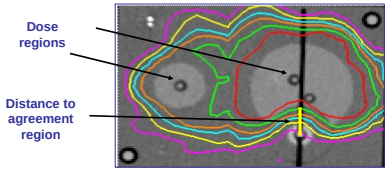
The institution is instructed to give 6.6 Gy to at least 95% of the primary PTV. 5.4 Gy should be given to at least 95% of the secondary PTV. The organ at risk is limited to less than 4.5 Gy.

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



The figure shows how the criteria are applied in the head and neck phantom.

Results:

Between 2001 and June 2008, the head and neck phantom was irradiated by 416 institutions for a total of 572 irradiations. As of June 2008, 135 of the irradiations failed the criteria for an overall pass rate of 75%. The overall pass rate as of early 2007 was 74% as of mid 2005 was 71%, and as of mid 2003 was as low as 57%. The overall passrates were determined by total number of irradiations. An institution could have irradiated the phantom multiple times before passing.

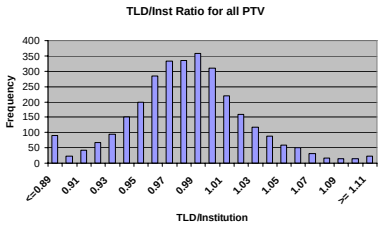
When all irradiations are considered, only 76% passed the criteria on the first irradiation attempt. As of early 2007, only 66% of institutions had passed on the first attempt.

93 of the failures were dose discrepancies measured with TLD, 16 were dose distribution discrepancies measured with radiochromic film and 26 were disagreements in both dose and dose distribution. Reasons for failure included inadequacies in beam modeling, set up errors, inaccurate data input into treatment planning systems, and malfunctions in delivery hardware.

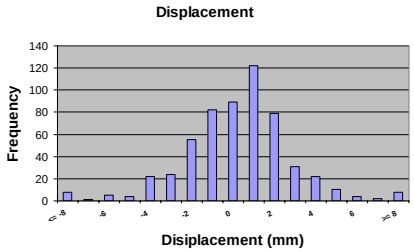
The following table shows the average TLD and film results from the 572 irradiations.

	1PTVsup	2PTV	OAR	Displ.(mm)
mean	0.98	0.98	1.00	0.3
std dev	0.055	0.045	0.19	3.0
count	2059	1026	1026	568
range	0.44 - 1.26	0.66 - 1.23	0.27- 2.24	-15 - 17

The following histograms show the spread of the results from the TLD in the PTVs and the spread of the DTA results. A negative DTA means that the institution delivered dose posteriorly into the spinal cord beyond the plan and a positive DTA means that the delivered dose fell off faster than the planned dose.



Results continued:



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

Treatment planning system	Pass Rate (%)	Attempts	Criteria Failed		
			Dose	DTA	Dose and DTA
BrainScan	88	16	2	0	0
CMS XiO	73	83	12	3	7
Corvus	76	33	7	0	1
Eclipse	84	154	15	6	4
Pinnacle	71	226	48	6	12
TomoTherapy	84	43	6	1	0
Other	71	17	3	0	2
total		572	93	16	26

Linear Accelerator Manufacturer	Pass Rate (%)	Attempts	Criteria Failed		
			Dose	DTA	Dose and DTA
Novalis	100	7	0	0	0
Elekta	63	48	15	2	1
Siemens	67	76	18	2	5
TomoTherapy	84	43	6	1	0
Varian	79	398	54	11	20
total		572	93	16	26

IMRT technique	Pass Rate (%)	Attempts	Criteria Failed		
			Dose	DTA	Dose and DTA
Dynamic MLC	84	148	16	4	4
IMAT	71	24	6	0	1
Segmental	74	372	65	11	21
Solid Attenuator	0	2	2	0	0
TomoTherapy	84	25	3	1	0
total*		571	92	16	26

*IMRT technique was experimental for 1 failed irradiation

Manufacturer/TPS Combination	Pass Rate (%)	Attempts	Criteria Failed		
			Dose	DTA	Dose and DTA
Elekta/Corvus	0	1	1	0	0
Elekta/Eclipse	50	2	1	0	0
Elekta/Pinnacle	62	29	10	1	0
Elekta/XiO	100	9	0	0	0
Siemens/Corvus	88	8	1	0	0
Siemens/Eclipse	50	2	0	1	0
Siemens/Pinnacle	59	37	12	0	3
Siemens/XiO	68	22	4	1	2
Varian/Corvus	75	24	5	0	1
Varian/Eclipse	85	149	14	5	4
Varian/Pinnacle	75	160	26	5	9
Varian/XiO	77	47	6	1	4
total		490	80	14	23

Results continued:

The following shows the pass rate for the most common machine/TPS combinations through mid 2006. Earlier versions of Pinnacle did not include tools to help the physicist adequately model the rounded leaf ends of Varian machines.

Manufacturer/TPS Combination	Pass Rate (%)	Attempts	Criteria Failed		
			Dose	DTA	Dose and DTA
Varian/Eclipse	80	50	6	2	2
Varian/Pinnacle	70	56	11	3	3

The following shows the same results through mid 2008. Some of the overall improvement is believed to be due to improvements in Pinnacle software to better model rounded leaf ends. The Varian/Eclipse combination has also shown an improvement for which the reasons are not clear.

Manufacturer/TPS Combination	Pass Rate (%)	Attempts	Criteria Failed		
			Dose	DTA	Dose and DTA
Varian/Eclipse	85	149	14	5	4
Varian/Pinnacle	75	160	26	5	9

Conclusions:

Institutions interested in participating in NCI sponsored IMRT protocols appear to be delivering IMRT more accurately today than they were several years ago. One of the reasons for this is improved modeling capabilities in treatment planning systems. One of the most common treatment machine/planning system combinations has shown an improvement in pass rates since a new version of software became available. However, this does not explain all of the improvement. Other reasons could include more care taken at the time of phantom irradiation and increased knowledge in the medical physics community of how to adequately commission IMRT systems. Though there has been improvement, there is still room for more. 24% of the irradiations are still failures. Adequate IMRT quality assurance and commissioning is essential now as always.

Acknowledgements:

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References:

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