Quality Audits of the Calibration for TG-51 Non-Compliant Beams by the Radiological Physics Center

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Purpose

The Radiological Physics Center (RPC), since 1969, has been conducting quality audits of radiotherapy facilities to assure the National Cancer Institute that patients entered onto clinical trials receive comparable and accurate doses. The RPC's quality audit program includes on-site dosimetry review visits to participating institutions, anthropomorphic QA phantoms, review of patient and benchmark cases, credentialing for participation in specific protocols and annual machine output checks with our mailable TLD program. Recently, the use of new treatment machines to treat clinical trial patients that have TG-51 non-compliant megavoltage beams has been observed. A TG-51 non-compliant beam is defined as a megavoltage beam that by it's limitations due to the geometry and physical limitations of the machine or by the radiation type does not conform to the requirements specified within the TG-51 calibration protocol[1]. Machines with TG-51 non compliant beams include the Hi-Art TomoTherapy, Elekta Gamma Knife, Accuray CyberKnife and various proton machines, has required the RPC to monitor the reference calibration of these treatment machines.

Materials/Methods

Audits of TG-51 non-compliant beams were performed on the Hi-Art TomoTherapy, Elekta Gamma Knife, Accuray CyberKnife and various proton machines used to treat patients entered onto cooperative clinical trials. The majority of the audits were performed using the RPC's TLD program. The RPC uses TLD-100 from Harshaw in powder form. The TLD readings were corrected for linearity, fading, energy dependence and sensitivity (cGy/reading) referenced to a TG-51 determined dose rate in a ^{60}Co beam. Figure 1 shows the various TLD miniphantoms that were sent to institutions to be irradiated. Standard RPC TLD blocks and special TLD miniphantoms were made to accommodate the physical restrictions of the various treatment machines. The standard RPC TLD blocks were used for the Tomotherapy, CyberKnife and proton machines. A special TLD cassette that accommodated the RPC TLD and would fit within the Leksell QA dosimetry sphere was built. Another TomoTherapy miniphantom in the shape of a cylinder was also built to audit the machine output delivered dynamically. TLD were sent to participating institutions along with their normal TLD shipments with the exception of the proton machines. Each proton facility received a separate unique TLD shipment. Table 1 lists the irradiation conditions for each of the treatment machines. Proton beams were assessed at two points in a spread out bragg peak.

Ion chamber measurements were made in water phantoms on 3 Cyberknife, 3 Tomotherapy and 2 proton machines during on site dosimetry review visits to seven different institutions following the Accuray calibration procedure[2], a TomoTherapy procedure outlined by Thomas et al[3] and the IAEA TRS 398 protocol[4] for calibrating proton beams, respectively.

Materials/Methods continued

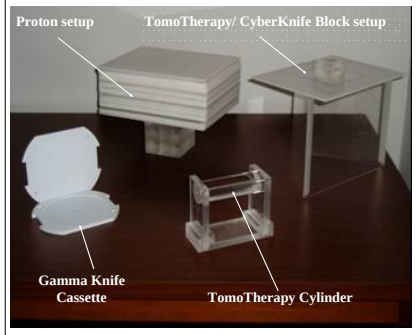


Figure 1. The various TLD miniphantoms used to perform the machine output audits of the CyberKnife, Gamma Knife, Hi-Art TomoTherapy and proton synchrotron/cyclotron machines.

Machine	Energy	SAD (cm)	Field Size	Dose Spec. Depth
CyberKnife	6 MV	80	6 cm dia.	d_{max}
TomoTherapy	6 MV	85	40 x 5 cm^2	d_{max}
Gamma Knife	^{60}Co	40	1.8-1.6 cm dia.	8 cm
Proton	152-250 MeV	230-320	10x10 to 24 cm dia.	Mid SOBP

Table 1. The irradiation conditions for the TLD audits of the TG-51 non-compliant beams for the CyberKnife, Gamma Knife, Hi-Art TomoTherapy and proton synchrotron/cyclotron machines.

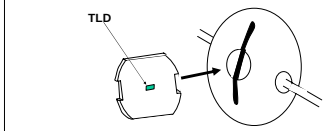
Example of Irradiation Instructions

RPC Gamma Knife TLD Phantom

Guidelines for irradiating the RPC Gamma Knife TLD Phantom.

Procedures:

1. Note that the RPC Gamma Knife TLD phantom is identical to the Leksell Radiation Phantom TLD cassette that slides into the Spherical dosimetry phantom (figure 1). There are two TLD capsules in the center of the RPC Gamma Knife TLD phantom.
2. Please assemble the Leksell Spherical dosimetry phantom in the Gamma Knife unit and slide the RPC Gamma Knife TLD phantom into the slot in the sphere.
3. Using 18 mm cones, deliver a dose of 6 Gy to the RPC TLD. The TLD are located in a volume that is 8 mm x 8 mm x 4 mm in the center of the RPC Gamma Knife TLD phantom and is located symmetrically about the center of the spherical dosimetry phantom. Please endeavor to deliver a uniform dose of 6 Gy to the RPC TLD volume described above.
4. Return the RPC Gamma Knife TLD phantom to the RPC.



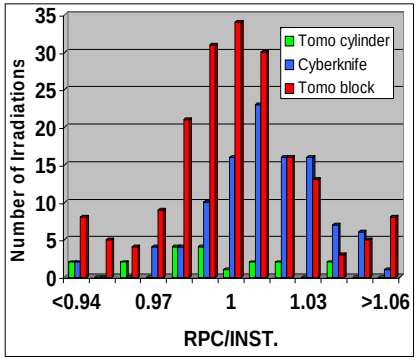
Results

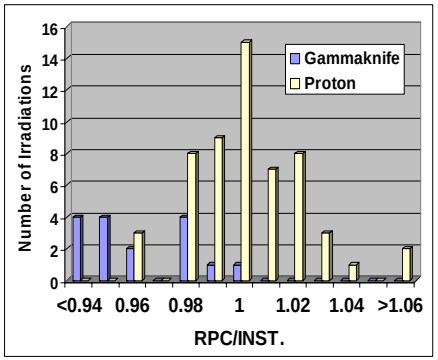
	TomoTherapy Cylinder	TomoTherapy Block	CyberKnife	Gamma Knife	Proton
avg. TLD RPC/INST	0.980	1.002	1.008	0.962	1.003
std. deviation	0.060	0.050	0.047	0.022	0.022
count	19	186	105	16	56

Table 2. TLD results for the various TG-51 non-compliant machines. With the exception of the Gamma Knife, the average RPC/INST ratios all fall within 2% , however the standard deviation for the TomoTherapy and Cyberknife beams is 5-6% indicating a wide range of results. The proton beam results have the best overall statistics.

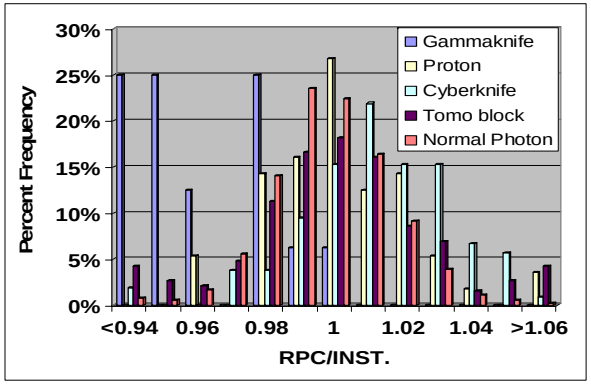
	CyberKnife	TomoTherapy	Proton
avg. ion chamber RPC/INST	0.998	1.008	1.004
std. deviation	0.010	0.011	0.005
count	3	3	6

Table 3. Ion chamber results for the few TG-51 non-compliant machines that have been measured during dosimetry on-site review visits.





Frequency histograms of the RPC/INST ratios for the TG-51 non-compliant beams. Most of the non-compliant beams fall within the ±5% criterion except for the Gamma Knife results which were on average 4% low. Approximately 9% of the non-compliant beams audited were equal to or greater than the RPC's 5% criterion.



Percent frequency histogram of the RPC/INST ratios for the TG-51 non-compliant beams measured to date compared to the normal TG-51 compliant photon beams (n=6000). With the exception of the Gamma Knife, the distribution of results for the TG-51 non-compliant beams is the same as for the compliant beams. Gamma Knife shows a 4-5% low result of which 1% is due to the muscle to water conversion and the remaining 3% due to differences between TG-21 in polystyrene and TG-51 in water dose calculations.

Conclusion

Audits of the calibrations of TG-51 non-compliant beams have shown that the majority of the institutions are within the RPC's ±5% criterion, however since 9% of the beams tested were at the 5% criterion or outside of it, vigilance is warranted. A TG-51 dose to water type of protocol should be developed for the Gamma Knife calibrations.

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References

[1] P.R. Almond, P.J. Biggs, B.M. Coursey, W.F. Hanson, M.S. Huq, R. Nath and D.W.O. Rogers, " AAPM's TG-51 protocol for clinical reference dosimetry of high-energy photon and electron beams," Med. Phys. 26, 1847-1870 (1999).

[2] S.D. Thomas, M. Mackenzie, D.W.O. Rogers and B.G. Fallone, A Monte Carlo derived TG-51 equivalent calibration for helical tomotherapy, Med. Phys. 32, 1346-1353 (2005).

[3] Accuray Physics Manual, Module 3: Commissioning Linac and Annual QA "CyberKnife Absolute Dose Calibration", Sunnyvale, CA.

[4] IAEA (International Atomic Energy Agency), Absorbed Dose Determination in External Beam Radiotherapy. An International Code of Practice, Technical Report Series No. 398 (IAEA, Vienna, 2000), pp. 125-150.